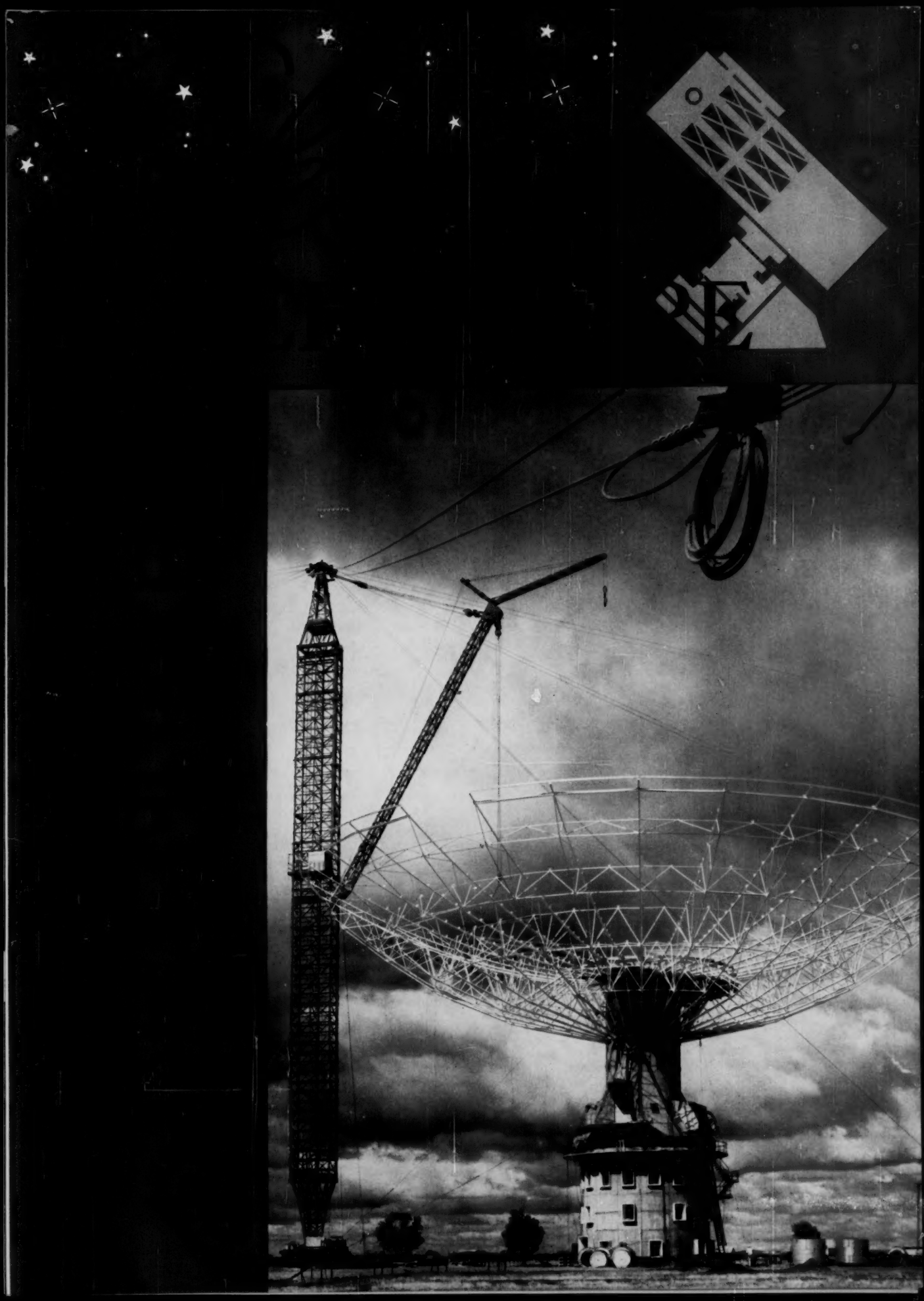

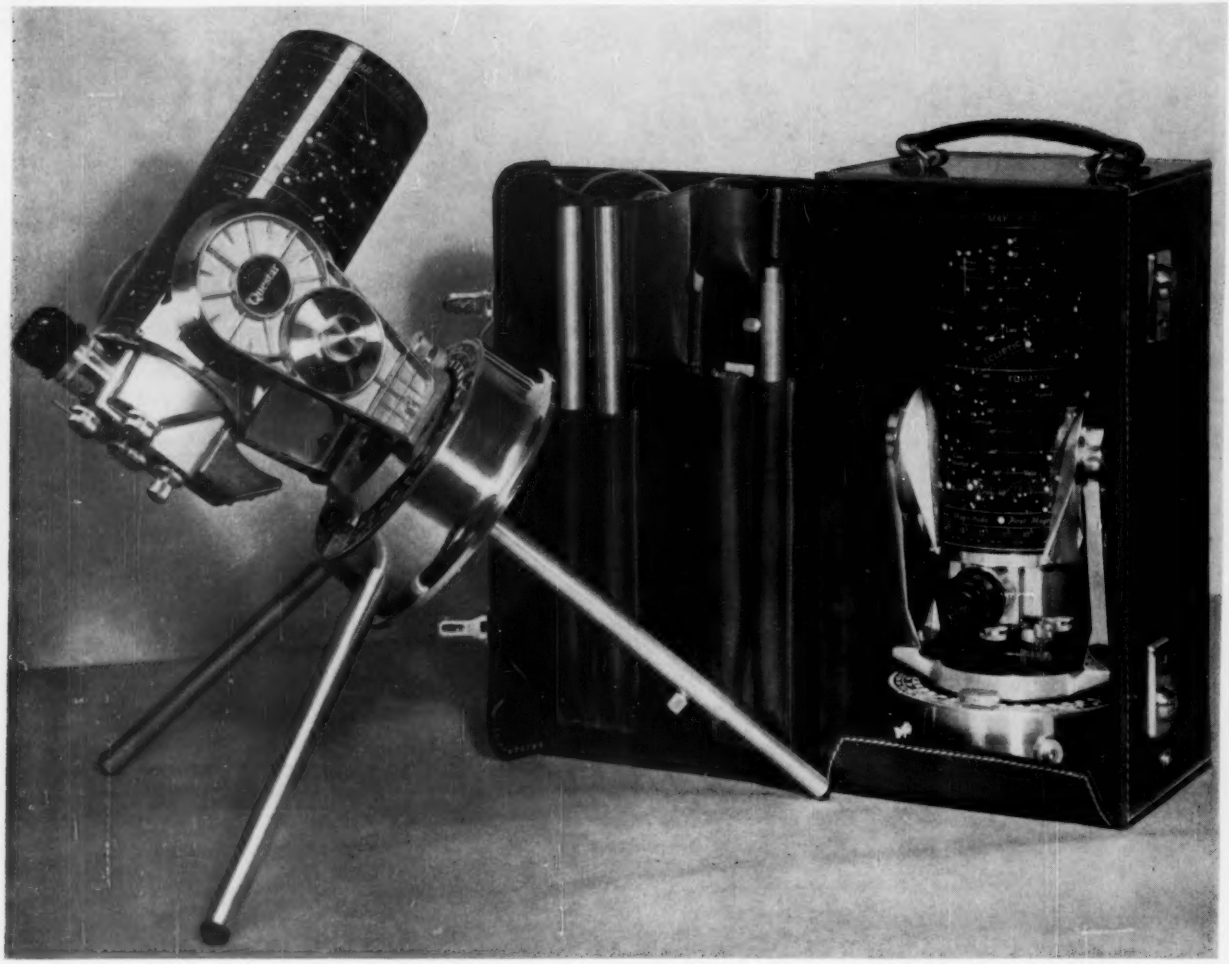

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When you've had enough of heavy loads, of quivering tubes and images, enough of drives that falter and slow motions that fall short —

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QUESTAR

NEW HOPE, PENNSYLVANIA

Sky and TELESCOPE

CHARLES A. FEDERER, JR., *Editor*
JOSEPH ASHBROOK, *Technical Editor*

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Vol. XXII, No. 2 AUGUST, 1961

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COVER: The world's second largest steerable radio telescope, as it appeared a few months ago during construction of its paraboloidal radiation collector, 210 feet in diameter. It is being erected at a latitude of 33° south, near Parkes, New South Wales, Australia, by the Commonwealth Scientific and Industrial Research Organization, for radio studies of the Milky Way and other galaxies. The feed antennas and preamplifiers will be carried on a tripod support, the dish having a focal length of 86 feet. See page 87 of this issue for another view of the main dish. Photograph from Radiophysics Division, C.S.I.R.O.

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More About the Earth's Cloud Satellites

THIS YEAR'S most unexpected astronomical news is the discovery of two faint cloudlike satellites of the earth, which can be seen with the unaided eye under exceedingly favorable circumstances. These objects, found by K. Kordylewski of Krakow Observatory in Poland, are traveling in nearly circular orbits at the same distance as the moon.

On page 10 of the July issue a brief report was given, based on the very limited information then available. The clouds travel in the same path as the moon, but about 60 degrees behind it. They are thus in the vicinity of the so-called L_5 libration point in the Earth-Moon system, where it is known from theory that a small satellite can remain in stable motion.

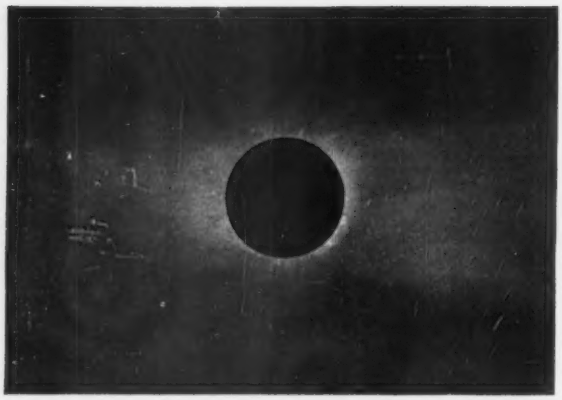
In a letter to the Smithsonian Astrophysical Observatory and to SKY AND TELESCOPE, Dr. Kordylewski has given some details of his discovery.

Ten years ago he began a telescopic search for faint starlike objects near the L_5 point and the analogous L_4 libration point, which stays 60 degrees ahead of the moon. At that time, the Polish astronomer was hoping to detect single meteoroids, visible by reflected sunlight, that might be circling the earth. No such objects as bright as magnitude 12 were found. Then Prof. J. Witkowski of Poznan Observatory suggested to him that a swarm of tiny particles, though individually undetectable, might be visible as a faintly luminous patch.

Beginning in October, 1956, on a number of occasions Dr. Kordylewski saw with the naked eye slight brightenings in the sky near the L_4 and L_5 points. These difficult sightings were made in the very dark, pure sky of high mountain stations in Czechoslovakia, on Mts. Lomnica and Kasprowy Wierch, and at Skalnate Pleso. The luminous patches appeared to be at least two degrees in diameter, and were a magnitude or two fainter than the central part of the gegenschein. In a few cases, the Polish astronomer could observe such a patch on consecutive nights, confirming that it was moving at the same rate as the moon.

A special combination of circumstances is needed to make the clouds observable. Because they shine by reflected sunlight, they will be brightest when nearly opposite the sun. At such times, however, the moon will be gibbous; hence sightings will be possible only when it is below the horizon. Simultaneously, the libration point has to have a considerable altitude, to lessen atmospheric dimming. A further restriction is that the position lie clear of the disturbing light of the Milky Way and the gegenschein.

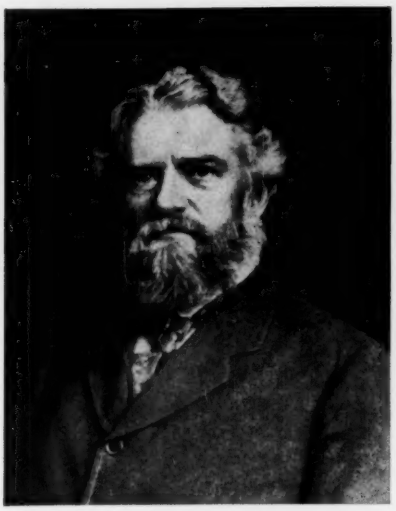
(Continued on page 83)



This contemporary drawing of the May 28, 1900, total solar eclipse was based on photographs. From "The Observatory."

Astronomy in 1900

OTTO STRUVE, *National Radio Astronomy Observatory**



Canadian-born Simon Newcomb (1835-1909) was a dominating figure in American astronomy. His chief work dealt with star positions, motions of the moon and planets, fundamental constants, and ephemerides.

RECENTLY a publisher asked me to prepare a short book on the history of astronomy in the 20th century. Therefore, to clarify my ideas concerning the state of the science at this period's beginning, I started by looking at the happenings of 1900, although the century did not formally begin until January 1, 1901.

In the September, 1960, issue of *Physics Today*, I expressed the opinion that while currently there is an explosive growth of observational astronomy, we are also living in "a period of vigorous, though much more gradual, increase of ideas, which has little or no relation to the sputniks and which began in the early years of this century, through the work of Emden, Schwarzschild, Hale, Kapteyn, Eddington, Jeans, Russell, and many others, and which is still gaining momentum through the work of a dozen or more brilliant astronomers of our own generation." This view is borne out by a look back at the activity of the turn of the century.

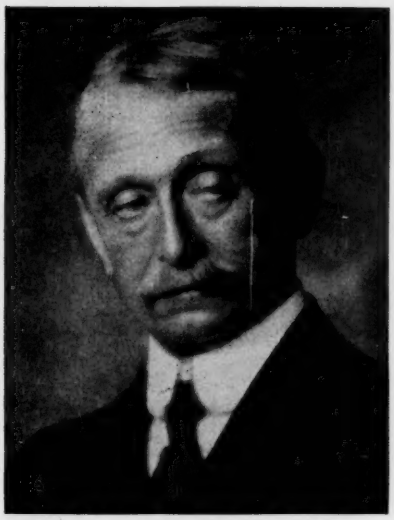
The two main astronomical happenings of 1900 were the near approach to the earth of the newly discovered minor planet Eros and the total solar eclipse of May 28th, observable from the United States, Portugal, Spain, and Africa.

These events attracted the attention of many astronomers in all parts of the world, and the astronomical publications of 1900 and 1901 contain numerous accounts of successful observations of the eclipse, and of detailed plans for positional measurements of Eros. The significance of the latter work was that this asteroid offered an unexcelled opportunity for a precise determination of the astronomical unit (the mean distance between the earth and the sun). The importance of Eros for this purpose was discussed by Simon Newcomb before the American Astronomical Society at New York City in June, 1900, as follows:

"Some one has divided astronomers into two classes, those who talk about things to be done, and those who go to work and do them. In the present case I am afraid we shall have to enroll ourselves in the first class, because it is not easy to do anything in this matter, the situation in this country not being favorable to the determination which we have in view. You are doubtless all aware of the great interest attaching to this remarkable asteroid. It may be said to supply us with what we have long been wanting, an object admitting of exact observation, which at proper intervals will come so near the earth that the solar parallax can be determined with greater precision than by any other method. It would hardly be possible to get one more exactly to fill the bill. The minimum distance of Eros from the earth is 0.15 of the distance of the earth from the sun. It follows, therefore, that at certain times it will be about as near to us as observations can advantageously be made. Were it to come very much nearer the additional advantage would be slight, for the reason that the elements of its orbit could hardly be known with sufficient accuracy to give us greater advantage; 0.15 is all we can ask for, since that distance will diminish the

Part of Greenwich Observatory as it appeared around the turn of the century. This dome contained the 26-inch Thompson photographic refractor. In 1900 it was used to take 161 photographs of Eros when that asteroid was close to Earth. Other large Greenwich instruments then were the 28-inch refractor, for double star work, and the 8-inch Airy transit circle.

*Operated by the Associated Universities, Inc., under contract with the National Science Foundation.



Today's flourishing Dutch school of Milky Way specialists began with J. C. Kapteyn (1851-1922), director at Groningen. He made pioneer studies of the arrangement of stars in space, and investigated statistically stellar motions, distances, and brightnesses.

effect of errors of observation by six or seven times. We have made very little progress in this direction for 50 years, and may now hope for something more. Yet in Eros, the Fates or whoever rules our destiny, have supplied us with something very tantalizing. It turns out that the nearest approach of Eros to the earth occurs only on rare occasions. A nearest approach occurred in 1894, and another approach as near as that will not occur until after the middle of the coming century. But an approach as near as can occur in the next 20 years will take place in the coming autumn, when its minimum distance from the earth will be about 0.3, or twice its absolutely shortest distance. It is very desirable that astronomers who devote their attention to the determination of the solar parallax, should take advantage of this opportunity for we shall have a parallactic displacement of Eros exceeding three times and possibly five times the solar parallax. But there are many drawbacks, the planet is faint; it will probably be, when nearest to us, but little above the ninth magnitude, and it will therefore be scarcely possible from its rapid motion to photograph it, or to ascertain its true position upon the plate at any given time. It is difficult to ascertain just how the observations upon it should be made."

An international astrographic conference took place at Paris in July, 1900, at which "in conformity with the expressed objects of the conference, a special committee was appointed to prepare a general plan for systematic observations of Eros at the coming opposition, by which the widest co-operation of the observatories of the world would be secured." This committee prepared a set of resolutions and recommendations to guide the astronomers in planning their work most effectively.

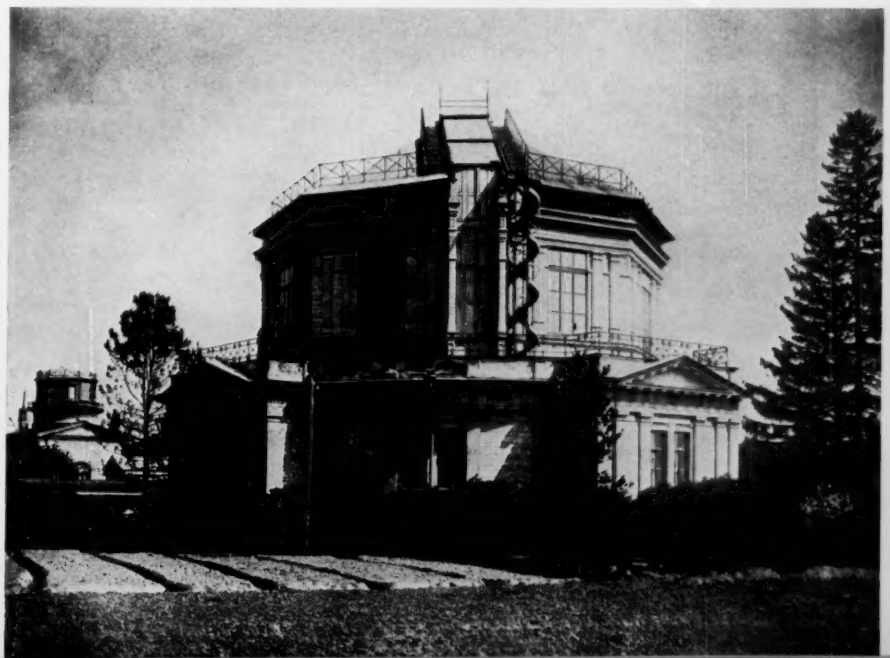
The labor required to determine the astronomical unit from Eros observations was immense. Not only was it necessary to measure many times with highest precision the co-ordinates of Eros with respect to a selected list of comparison stars, but the positions of most of the comparison stars had first to be determined with respect to brighter stars whose co-ordinates and proper motions were already adequately known. The final results of the world-wide campaign were reported in 1909 by A. R. Hinks, who found from the photographic observations 8.807 seconds of arc for the solar parallax, corresponding to 92.82 million miles for the astronomical unit. An even more extensive Eros campaign was carried out in 1930-31. The most recent determination of the astronomical unit is from the Jet Propulsion Laboratory's radar contact with Venus in early 1961, giving 92.96 million miles. It is quite possible that Eros will not be used again for measurements of solar parallax, because modern electronic techniques are capable of giving much higher accuracy.

In 1900 the principal national societies of astronomers were already active. The Royal Astronomical Society, founded in 1820, was holding regular meetings in London under the chairmanship of George Darwin and E. B. Knobel. The society had 635 fellows, and there were 48 foreign associates, most of them from countries outside the British empire.

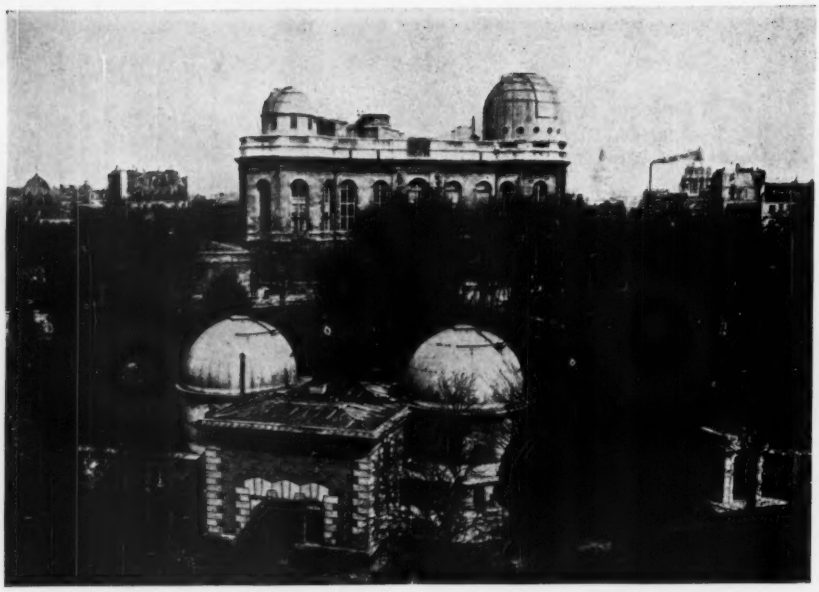
Henri Poincaré (1854-1912), French mathematician and astronomer, greatly advanced celestial mechanics.

A special issue of the society's *Monthly Notices* was devoted to reports of the May eclipse. It told of the British expeditions to Spain, Portugal, and Algeria, led by Sir Norman Lockyer, H. H. Turner, H. F. Newall, J. Evershed, R. Copeland, W. H. M. Christie (the Astronomer Royal), and F. W. Dyson. Their observations included direct photographs of the corona, and pictures of the flash and coronal spectra.

An important event of the year at the Royal Astronomical Society was the award of its gold medal to Henri Poincaré, the famous French mathematician and astronomer. In his presidential address to the society, Darwin described Poincaré's theoretical contributions in three fields: ocean tides, the figures of equilibrium of rotating fluid masses, and his monumental



The 30-inch Clark refractor occupied this dome at Pulkovo Observatory in Russia, which in 1900 was the best-equipped institution in Europe devoted to positional astronomy. Completed in 1839, Pulkovo soon gained fame from its precise star catalogues and from Otto Struve's double star work. The 30-inch Clark, built in 1884, was used by Hermann Struve for Saturn's satellites and by A. Belopolsky for measuring stellar radial velocities.



Paris Observatory at the turn of the century was the center of a great international undertaking to catalogue from photographs all stars brighter than about 11th magnitude, and to chart all brighter than magnitude 14. Paris undertook to do this for the zone of declination between +24° and +18°; the remainder of the sky was divided among 17 other observatories spread over the globe from Finland to Australia.

work in celestial mechanics, which had been published in 1892-99 as *Les Méthodes Nouvelles de la Mécanique Céleste*. Darwin concluded his eulogy with the words:

"The leading characteristic of M. Poincaré's work appears to me to be the immense wideness of the generalizations, so that the abundance of possible illustrations is sometimes almost bewildering. This power of grasping abstract principles is the mark of the intellect of the true mathematician; but to one accustomed rather to deal with the concrete the difficulty of completely mastering the argument is sometimes great. To the latter class of mind the easier process is the consideration of some simple concrete case, and the subsequent ascent to the more general aspect of the problem. I fancy that M. Poincaré's mind must work in another groove than this, and that he finds it easier to consider first the wider issues, from whence to descend to the more special instances. It is rare to possess this faculty in any high degree, and we cannot wonder that the possessor of it should have compiled a noble heritage for the men of science of future generations."

At Heidelberg, Germany, Max Wolf (1863-1932) introduced photographic methods greatly increasing the number of asteroid discoveries. The North America nebula was found and named by him. Wolf discovered numerous proper-motion stars, variables, and galaxies, using a 16-inch refractor.

In Germany, the great national astronomical organization was the Astronomische Gesellschaft, founded at Heidelberg in August, 1863. This society was the only one that attempted to maintain an international character. Its meetings were usually held alternately in Germany and outside the country. The council always consisted of approximately equal numbers of German and non-German astronomers. The 18th meeting of the Gesellschaft was held at Heidelberg, on August 8-11, 1900. Hugo von Seeliger of Munich was president, and the council members were E. Weiss (Vienna, Austria), N. Dunér (Uppsala, Sweden), M. Nyrén (Pulkovo, Russia), A. C. Oudemans (Utrecht, Netherlands), and the Germans R. Lehmann-Filhés (Berlin), G. Müller (Potsdam), and H. Bruns (Leipzig). At the time the society had 363 members.

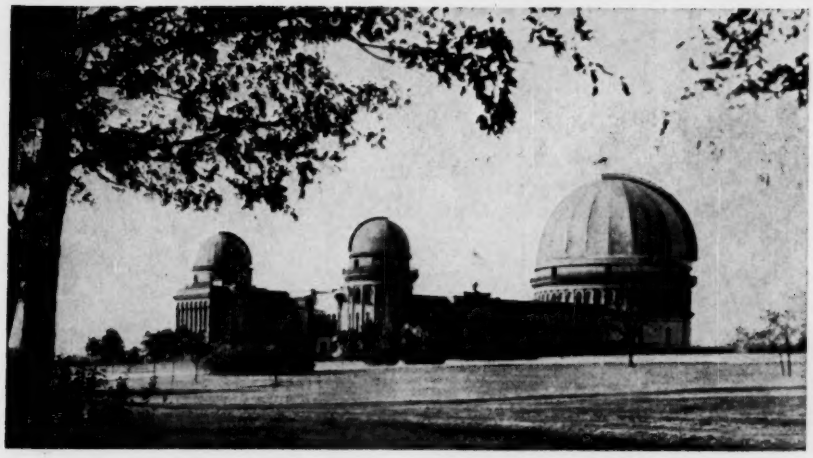
Seeliger was still president of the Gesellschaft at the 1913 meeting, held at Hamburg in connection with the completion of the Bergedorf Observatory. While I was still going to high school, I attended this gathering with my father, and I remember meeting the famous Munich astronomer. Some of the younger Germans opposed the re-election of Seeliger to another term of office, but the revolt fizzled out, and Seeliger received a large majority.

Only a short while ago, at the National Radio Astronomy Observatory, I had the pleasure of meeting Burt L. Newkirk, who had studied astronomy under Prof. F. P. Leavenworth at the University of Minnesota, and later went to Munich for two years, where he obtained his doctor's degree under Seeliger. Dr. Newkirk told me that the latter was a kind and considerate person, taking a close interest in the many foreign students who came to work with him. Seeliger was born in Austria, became the director of Gotha Observatory in 1881, but transferred to Munich in the following year. He is best known for his work in theoretical photometry (he was first to predict the increased surface brightness of Saturn's rings at opposition), and for his remarkable series of articles on the space distribution of the stars in the Milky Way.

At Munich, Newkirk also met Karl Schwarzschild, who was just beginning his astronomical career. When Schwarzschild went to Göttingen, he persuaded Newkirk to go to that university, where the young American attended the lectures of the mathematicians David Hilbert and Felix Klein.

Among the most interesting papers presented at the 1900 Gesellschaft meeting was Schwarzschild's "Concerning the Possible Measure of Curvature of Space." Although at that time the theory of relativity was still unknown, Schwarzschild

Influential teacher and gifted theoretician, Hugo von Seeliger (1849-1924) was director of Munich Observatory. He applied optical theory to investigate many solar system problems. In his studies of galactic structure, Seeliger was among the first to realize the importance of interstellar dust.



Yerkes Observatory's 40-inch refractor, in the dome at the right, was put into service on May 21, 1897. The first meeting of the American Astronomical Society was held inside this dome that October. Early work done with the 40-inch telescope included G. E. Hale's solar observations, G. W. Ritchey's lunar photographs, and E. E. Barnard's double star measures.

was aware of the importance of non-Euclidean geometry. Referring to an article by H. von Helmholtz, he comments: "We find ourselves – if we want to – in a geometrical fairyland, but the beauty of this fairyland is that it may be real after all. The question should now be considered how far we have pushed the borders of this fairyland, how minute the curvature of space is, and how large a radius of curvature should be assumed."

The German astronomer's final conclusion was, "It is possible, without contradicting the evidence, to think of the universe as contained within a hyperbolic (pseudospherical) space with a radius of curvature larger than 4,000,000 radii of the earth's orbit, or within a finite, elliptical space with a radius of curvature larger than 100,000,000 radii of the earth's orbit, while assuming in the latter case an absorption of light equal to 40 magnitudes in one journey around this space."

Although we know today that the possible radius of curvature of the universe must be many times greater than the minimum values quoted by Schwarzschild, his paper represents a powerful effort to solve what is now called the cosmological problem.

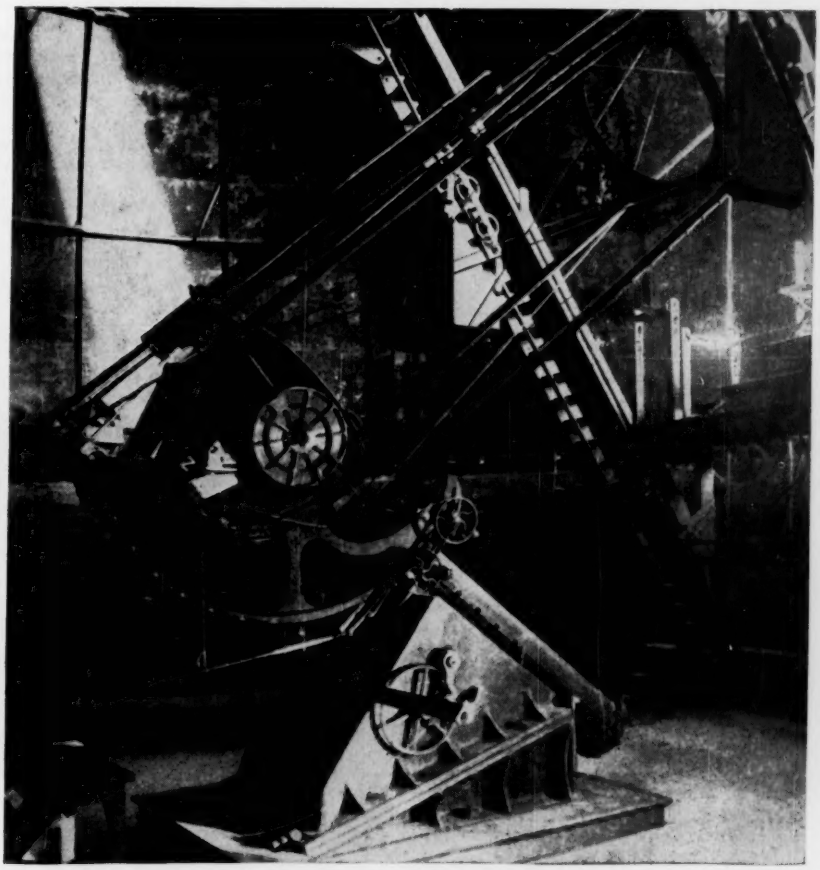
An important service rendered by the Astronomische Gesellschaft for about half a century was its annual catalogue of variable stars, published in its *Vierteljahrsschrift* (Quarterly Report). The 1900 listing, prepared by E. Hartwig of Bamberg, Germany, contained 360 stars. The latest catalogue of variables, published in 1958 by B. V. Kukarkin and his coworkers at Moscow, tabulates 14,708 stars known to have changed in brightness.

At the Gesellschaft's 1900 meeting, Arthur Auwers of Berlin reported on the progress of the immense plan to catalogue the positions of all stars brighter than magnitude 9.1 and north of declination −18°. This co-operative project of a dozen observatories in Europe and America was successfully completed a few years later. To this day, the resulting AG catalogues have remained an important source of data for determining the proper motions of stars.

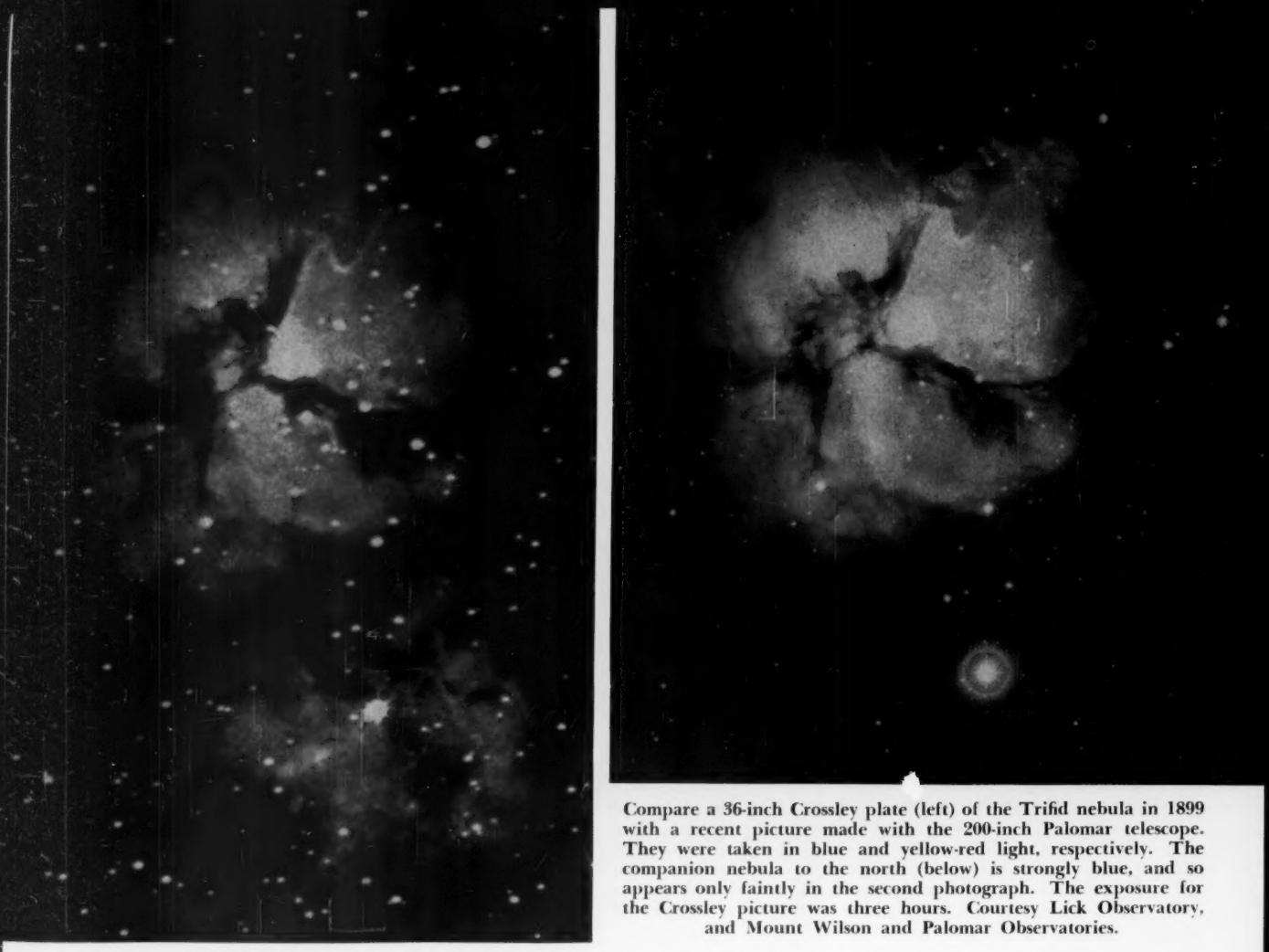
The Astronomische Gesellschaft retained its international character until the first world war, and attempted to renew it in the years of peace that followed. However, a much more representative society of the astronomers of many nations was created through the initiative of G. E. Hale in 1904, under the name of the International Solar Union. In 1919 it became the International Astronomical Union, which serves to this day as the only truly worldwide astronomical organization. By 1959 the IAU had 1,120 members. It is meeting in California this month.

The American Astronomical Society was founded in 1897 at the dedication of Yerkes Observatory, and another organizing conference was held at Harvard the following year. The first regular meeting took place at Yerkes in 1899, and the 1900 session was in June, at Columbia University in New York City. The original number of members was 113, and by 1900 this had grown to nearly 150.

The *Astrophysical Journal* was five years old in 1900, having been started by Hale at Yerkes in 1895. A glance through its pages gives a good idea of the problems in astrophysics that were attracting attention at the turn of the century. In



The 36-inch Crossley reflector of Lick Observatory, as it appeared in 1900. That year, J. E. Keeler reported from his Crossley photographs that at least 120,000 "nebulae" were within reach of this instrument, and that most have a spiral structure. Now modernized, this reflector is still an effective research tool. See the next page for an early Crossley photograph.



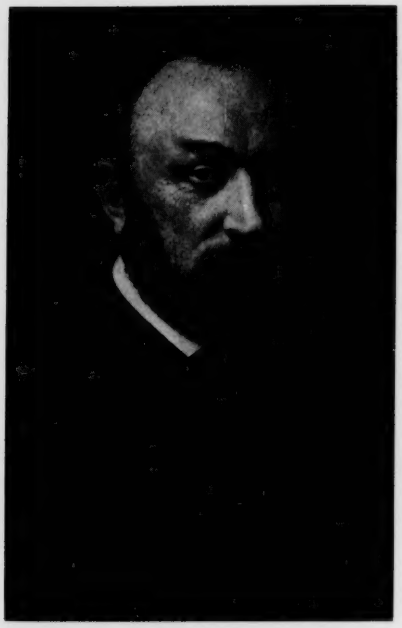
Compare a 36-inch Crossley plate (left) of the Trifid nebula in 1899 with a recent picture made with the 200-inch Palomar telescope. They were taken in blue and yellow-red light, respectively. The companion nebula to the north (below) is strongly blue, and so appears only faintly in the second photograph. The exposure for the Crossley picture was three hours. Courtesy Lick Observatory, and Mount Wilson and Palomar Observatories.

the September, 1900, issue, the Netherlands astronomer C. Easton published his famous theory of the Milky Way, which he concluded is, in effect, a spiral galaxy whose center is a considerable distance from the sun. Later work has resulted in drastic revisions to Easton's early attempt. For example, he placed the center of the system approximately in the direction of Cygnus, whereas we now know it is located much farther south, in Sagittarius. Nevertheless, his article had a profound effect upon later studies of the structure of the Milky Way.

A serious loss to American astronomy in 1900 was the premature death of James E. Keeler, director of Lick Observatory, and a brilliant astrophysicist. His last publication was an *Astrophysical Journal* article about the Crossley 36-inch reflector at Lick, an instrument that has rendered great services to photographic astronomy during the past 60 years. This telescope was made in 1879 by A. A. Common, of London, and was presented to Lick Observatory in 1898, where it has been used for direct photography of nebulae, spectroscopic studies of stars and emission nebulosities, and for measuring the radial velocities of very faint objects. Accompanying Keeler's article was the 1899 Crossley photograph of the Trifid nebula in Sagittarius that is reproduced here, whose good quality may be judged by comparison with a modern picture taken with the 200-inch Palomar telescope.

Also in the *Astrophysical Journal* for 1900 is an important article by F. G. Moulton of the University of Chicago, entitled "An Attempt to Test the Nebular Hy-

At Harvard Observatory 60 years ago, stellar spectra and the photographic and visual brightnesses of stars were major subjects. The dome in the center foreground housed an 11-inch refractor, and in the right background is the large dome of the famous 15-inch refractor. At that time Harvard also maintained a Southern Hemisphere station at Arequipa, Peru.



Harvard Observatory director E. C. Pickering (1846-1919) was a specialist in stellar photometry who personally made more than a million measurements of star magnitudes, and led the "Henry Draper Catalogue" program.

pothesis by an Appeal to the Laws of Dynamics." His main conclusion, that "certain phenomena . . . contradict the hypothesis so flatly that candid minds must admit that its validity in the form considered is open to serious question," was not accepted until years later. This was chiefly because of the appeal that Laplace's picture of the origin of the solar system had among those interested in its simplest aspects. Later work, however, has entirely upheld Moulton's skepticism. The Chicago astronomer is well-known today for an alternative theory — the planetesimal hypothesis — which he developed with the geologist T. C. Chamberlin.

No description of astronomy in those days can omit mention of measurements of the radial velocities of stars, an important branch of observational work that had recently attained greatly increased accuracy, thanks mainly to efforts of H. C. Vogel of Potsdam Observatory and W. W. Campbell at Lick. In the June, 1900, *Astrophysical Journal,* Vogel gave a useful summary of these revolutionary improvements. His measurements, made with only a small prism spectrograph, are comparable in precision with line-of-sight velocities obtained with much better instruments today.

With the 36-inch Lick refractor, W. W. Campbell (1862-1938) and his coworkers determined accurate radial velocities of all bright northern stars. They used a slit-spectrum method that was developed and refined by Campbell and is still in use today. He was director of Lick from 1901 to 1930.

LETTERS

Sir:

In "Questions from the S+T Mailbag" for April, it is reported that the North America nebula has been seen in telescopes as small as a 6-inch. I have often observed it with a 5-inch 20x apogee Moonwatch scope, a 7 x 50 monocular, and even the unaided eye. The borders of the nebula as seen with the naked eye fall within those shown in the Skalnate Pleso *Atlas of the Heavens.* With the Moonwatch scope, my borders match the *Atlas.*

I think that the nebula could be detected in any good instrument having an exit pupil over three millimeters in diameter. A key factor in observing it is that the sky be very dark.

KELLY L. COOK
5518 E. Rosewood
Tucson, Ariz.

Sir:

On page 326 of the June issue, Sergei Gaposchkin discussed the earliest observations of the supernova S Andromedae, which appeared inside Messier 31 in 1885, and concluded that maximum brightness took place on August 17th or 18th of that year. In the Scandinavian periodical *Nordisk Astronomisk Tidsskrift,* 1958, page 73, I had published a similar discussion, finding the time of maximum to be two or three days later.

Dr. Gaposchkin does not mention some observations by the English amateur astronomer P. H. Silcock (whose name has sometimes been incorrectly given as Schock or Slicock). The following report was published by Silcock in *The Observatory, 8,* 332, 1885:

"On August 17 and August 18 I saw the Andromeda nebula with my 3½-inch Cooke; the only note then made refers to my difficulty in getting definition. For a fortnight I did not use the glass; and on September 1st I noticed the new star. The appearance puzzled me considerably, and being but a beginner, I attributed it to some fault of my own. I was a good deal astonished on seeing Saturday's 'Times' to find that I was one of the first to see the star."

As Silcock took notes at the time of his observations, the probability of an error in date should be smaller than if he had to reconstruct the circumstances later from memory. But the observations contradict the one by L. Gully on August 17th, cited by Dr. Gaposchkin.

Gully himself stated (*Ciel et Terre,* Series 2, *1,* 355, 1885) that he did not realize he had seen an astronomical phenomenon until after he had read about it in an article in the preceding issue of the same periodical, which from internal evidence seems to have been written in early September. Gully does not refer to any notes of his own made at the time of observation. Writing at least three weeks after the event, he may have correctly remembered that the occasion was a public demonstration at his observatory on a Monday night. Perhaps, however, the actual date should be Monday, August 24th, just a week later. The new star was then of magnitude 6½, according to the Gaposchkin light curve, and the Andromeda nebula would still have presented a strange appearance.

If we adopt this date for Gully's observation, the contradictions disappear, and we can retain Isaac Ward's magnitude of 9½ on August 19th at 11 p.m. E. Hartwig made his discovery the following night. Hence the star brightened by three or four magnitudes in about 24 hours, and the time of maximum turns out to be not earlier than August 20th.

Until further facts become available, the two interpretations of S Andromedae by Dr. Gaposchkin and by myself seem equally likely. I agree with him that Ward's observation is difficult to use, because all details are lacking. But this Irish amateur appears to have had a fine insight into astronomy, and I prefer to retain his observation, though with low weight.

AXEL V. NIELSEN
Ole Roemer Observatory
Aarhus, Denmark

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Astronomers Meet at Nantucket

Lyman Spitzer, Jr. (left) of Princeton University Observatory ponders a point being made by K. Wurm of Hamburg Observatory in West Germany. Dr. Wurm, a noted authority on comets, opened a symposium on these objects. Dr. Spitzer has just completed a term as president of the American Astronomical Society. The new president is C. S. Beals, Dominion Observatory, Ottawa, Canada.

ON THE historic island of Nantucket off the Massachusetts coast, the nation's astronomers gathered on June 18-21 for the 108th meeting of the American Astronomical Society. Fortunately the event was scheduled well before the height of the island's tourist season, for the attendance was one of the largest in the society's history, with over 400 members and guests.

Arriving by plane, steamer, and yacht, they found themselves in an atmosphere little changed since the time of Nantucket's prosperity as home port for a great whaling fleet early in the last century. Cobblestones brought from Gloucester in 1837 still pave the main street, which was laid out nearly 150 years earlier. Old houses remain intact and newer ones follow the same architectural style — even the modern high school is finished in weather-beaten shingles.

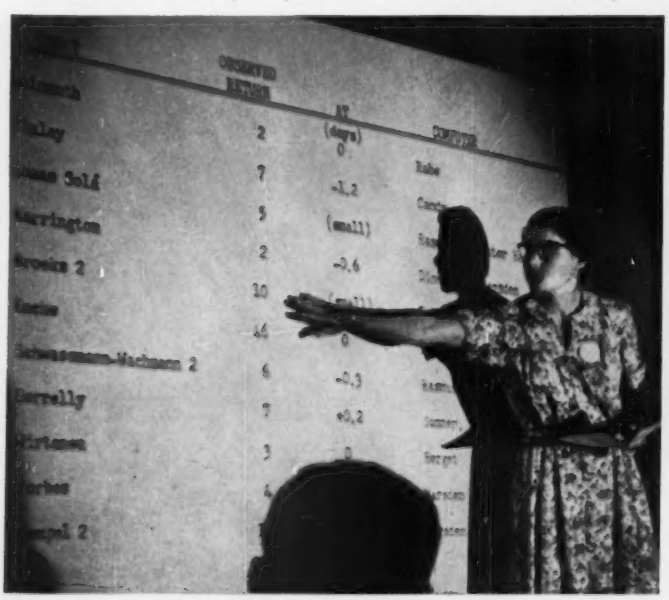
The busy program included a symposium on comets, the traditional society dinner, sight-seeing, the annual Russell lecture, and sessions for papers. A ladies' tour of historical buildings and a tea were given by the Maria Mitchell Association. This organization, which maintains Nantucket's well-equipped modern observatory, is named after the first American woman astronomer, who discovered a comet on October 1, 1847, and later was professor of astronomy at Vassar College.

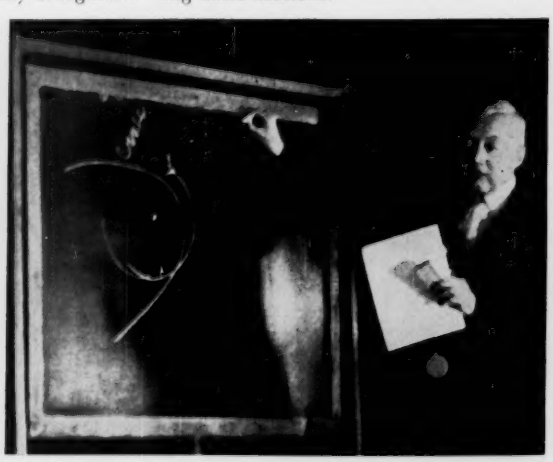
At its business meeting, the American Astronomical Society officially recognized the obstructions to future research that could arise from some types of space experiments, such as Project West Ford (see page 25, July issue). A resolution was passed expressing the society's concern over the contamination of the upper atmosphere and space. In addition, the resolution called for prompt reservation of certain radio frequencies for basic research.

The comet symposium was arranged by Dorrit Hoffleit, director of the Maria Mitchell Observatory. The six speakers were K. Wurm, Hamburg Observatory, West Germany; Elizabeth Roemer, U. S. Naval Observatory, Flagstaff, Arizona; William Liller, Harvard Observatory; Fred L. Whipple, Smithsonian Astrophysical Observatory; Ernst J. Öpik, University of Maryland; and B. Rosen, Liége, Belgium.

Dr. Wurm discussed the structure and development of comet tails. There are two types — strongly curved tails composed of minute solid particles, and nearly straight ones made up of gases. The former are usually only amorphous glows, but gas tails often show intricate, rapidly changing streamers.

For various comets, night-to-night sequences of photographs show that the streamers appear to approach the tail axis as they move backward from the head. As a result, the streamers seem to rotate around the head, the directions being opposite for streamers on opposite sides of the tail. Despite the many observations, there is yet no satisfactory theory explaining these motions.





Above: Ernst J. Öpik, University of Maryland, describes the perturbations of a comet by massive Jupiter.

Left: Elizabeth Roemer of the Naval Observatory's Flagstaff station discusses differences in the predicted and actual times of the returns of comets.

At Nantucket, J. Allen Hynek, Dearborn Observatory, concluded six years of service to the society as secretary. His successor is G. C. McVittie, University of Illinois Observatory.

A plea for more accurate measurements of comet positions was voiced by Dr. Roemer, who recommended especially the use of large telescopes. With these, very short exposures will show small, easily measured nuclei for many bright comets. Large apertures, too, permit photography of comets at great distances from the sun, thereby increasing the length of the orbital arc covered by observations.

A second recommendation by the Arizona astronomer was that perturbations of comets by the planets be calculated with greater precision. In several cases where the motion of comets had seemed to indicate a progressive acceleration, the effect could probably be explained instead by inaccurately computed perturbations.

Dr. Liller showed the results of his observations of several comets with a photoelectric device for scanning spectra. By comparing the intensity of a spectral emission feature of diatomic carbon with that of the continuous spectrum, which is sunlight reflected by solid particles, he could evaluate the relative amounts of gas and dust in a comet. Comet Encke contains very little dust, unlike the bright Comet Arend-Roland of a few years ago. The Harvard astronomer's work opens possible ways to evaluate the composition and sizes of the particles in comet tails.

The icy-conglomerate model for cometary nuclei was supported by Dr. Whipple. He pictured the nucleus of a large comet approaching the sun for the first time as a body of frozen gases intermingled with meteoric matter, having a mass of 10^{17} to 10^{19} grams and a radius of three to 15 kilometers. Dr. Whipple discussed the question of whether or not such a nucleus could resist tidal disruption when passing close to the sun.

From statistical arguments, Dr. Öpik arrived at the conclusion that certain asteroids such as Hermes and Apollo, with orbits crossing inside the earth's, may be "dead" comets that have lost all their gases. Perturbations by the planets should throw enough short-period comets into orbits of that kind to account fairly well for the known number of Apollo-type asteroids.

Dr. Rosen concluded the symposium by presenting slides of high-dispersion comet spectra taken at Haute Provence Observatory, comparing them with laboratory spectra of various gases. He expressed the hope that by simulating cometary spectra in terrestrial experiments it would be possible to ascertain the actual physical conditions in comets.

The 108th meeting of the American Astronomical Society, June 18-21, 1961, at Nantucket, Massachusetts. Host for the gathering was the Maria Mitchell Observatory. Photograph by Bill Haddon.

NEWS NOTES

CHANGING ORBIT OF COMET OTERMA

Of exceptional interest among periodic comets is one discovered on March 27, 1943, by Miss Liisi Oterma at Turku Observatory in Finland. The comet is traveling in a nearly circular orbit slightly smaller than Jupiter's, with a period of 7.9 years. From its motion, this object could be taken for a faint asteroid, were it not for its nebulous appearance. Like a minor planet, Comet Oterma 1942 VII can be observed every year, when near opposition.

In the year 1963, Comet Oterma will pass within nine million miles of Jupiter, and this very close encounter with the giant planet will drastically change the character of its orbit. The details of this transformation have been predicted by B. G. Marsden at Yale University Observatory. He began with the orbit as of 1958, derived by P. Herget. Taking into account perturbations of the comet by all planets from Venus to Saturn, Mr. Marsden computed its motion step by step up to 1966, using an IBM 650 electronic computer.

Most of the alteration in the orbit takes place in the first half of 1963. Within one 40-day interval the longitude of the ascending node moves 100 degrees westward. During the course of that year, the orbital eccentricity increases from 0.25 to 0.34, the perihelion distance from 3.0 to 5.1 astronomical units, and the period from 8.1 to 22 years.

After its encounter with Jupiter, Comet Oterma will, because of the increased size of its orbit, remain an exceedingly faint object, not brighter than magnitude 20. "It is unlikely that the comet will be observable after early 1966 until (perhaps) shortly before the next perihelion-passage in 1983," notes Mr. Marsden in the June *Astronomical Journal*.

Harvard professor Leo Goldberg, former director of the University of Michigan Observatory, is chairman of the United States national committee and a vice-president of the International Astronomical Union.

BIRD MIGRATION STUDIES

That migrating animals can time and orient their semiannual journeys by the sun and stars is a theory now being tested at planetariums in San Francisco, California, and Chapel Hill, North Carolina. At the Morehead Planetarium of the University of North Carolina, three Duke University scientists, P. H. Klopfer, K. Schmidt-Koenig, and G. M. Smith, are experimenting with a night-migrating white-throated sparrow, along lines developed by Franz Sauer in Germany and described by him in *Scientific American* for August, 1958. Dr. Sauer is concurrently working on the problem at the Morrison Planetarium in San Francisco.

In the Morehead experiment, a sparrow that has been conditioned to think that the season is spring is placed in a round wire cage, four feet in diameter and one foot high, under the planetarium sky set for a spring evening. The cage is fitted with perches that trip switches each time the bird lands; a graph recorder marks its movements during two hours.

Statistical analyses will show if there is a preference for the perch nearest north; such a preference may indicate that the sparrow is orienting itself by the stars.

IAU MEETING

A thousand astronomers from all over the world will gather in Berkeley, California, August 15-24, for the 11th General Assembly of the International Astronomical Union. The IAU is a world-wide professional organization that serves as a clearinghouse for astronomical information and the co-ordination of research. Its general assemblies, held every three years in a different country, provide stimulating personal contacts among widely separated astronomers working on similar problems.

The large body is divided into smaller commissions, each composed of researchers in some field such as meteors or variable stars. During the assembly, mornings will be devoted to meetings of these commissions. Afternoons and evenings will be filled by additional meetings, invited lectures, field trips, and sight-seeing. Before and after the August 15-24 gathering, several symposia are planned for invited specialists in space astronomy, galaxies, double stars, and the solar corona.

Two special tours for visiting astronomers will be conducted immediately after the close of the general assembly. They will include visits to Yosemite Valley, Glacier Point, Monterey, and Carmel. In addition, Mount Wilson and Palomar Observatories will be open to IAU members and guests.

IN THE CURRENT JOURNALS

SUBDWARF STARS, by Margaret and Geoffrey Burbidge, *Scientific American*, June, 1961. "It is our view, in any case, that the name 'subdwarf' is inappropriate for the majority of stars now so designated that fall below and parallel to the main sequence. It is still true, of course, that these stars are non-typical, both in their low metal content and in their high velocity relative to the sun. . . . They belong to other parts of our galaxy and just chance to be passing through the solar neighborhood."

ACTIVITIES IN ASTRONOMY, by Arthur G. Suhr, *Science Teacher*, May, 1961. "In addition to the experiments and demonstrations described, students in the [high school] astronomy unit learned to photograph star trails and experiment with lenses and mirrors to determine how images are formed in a telescope. Through the use of simple thermocouples, an explanation was given as to how star temperatures may be calculated."

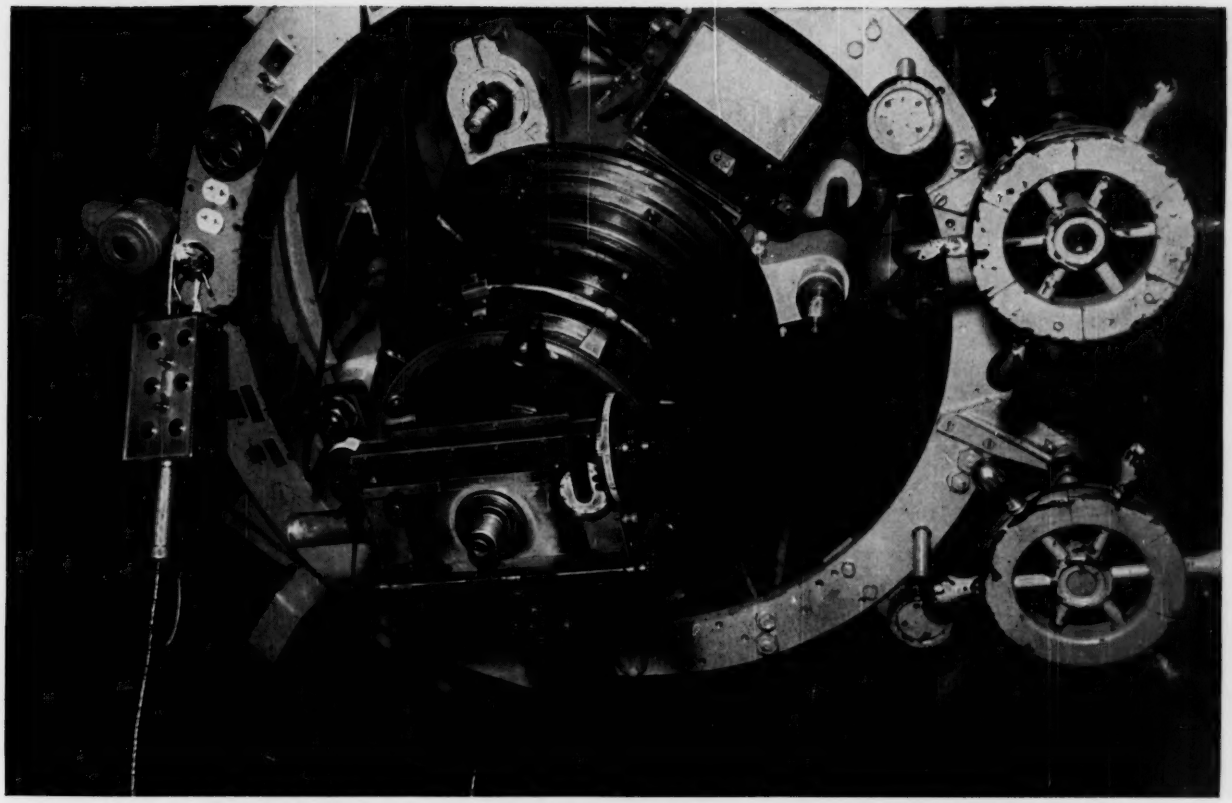
THE INTERPRETATION OF SOME CHANGES IN ORIENTATION OF A BINARY STAR ORBIT, by Martin Johnson, *Quarterly Journal* of the Royal Astronomical Society, Vol. 2, No. 1. "The whole study offers the fascinating proposition of obtaining information about the inaccessible interior of a star, notably the change in density and other distributions during hydrogen exhaustion, through observation of so completely external a phenomenon as the apse rotation in a binary gravitational companionship."

CALIFORNIA FIREBALL

In SKY AND TELESCOPE for April, page 222, several reports were given of a spectacular fireball that traveled seaward over California on January 16, 1961. A detailed investigation of this event has been made by John A. Russell, University of Southern California, who reported his results at the Astronomical Society of the Pacific's June meeting in Los Angeles.

Dr. Russell collected over 70 observations of this meteor, among which were three descriptions of its location with respect to the star background. "An orbit based on these observations," he said, "indicates that the meteorite was moving [around the sun] in a direct orbit of 14 degrees inclination, with an aphelion distance of about three astronomical units.

"The meteor broke into five parts before suddenly disappearing 20 miles east of Santa Maria, California, at a height of about 15 miles. The terrain beneath the point of disappearance is rough and uninhabited, except by occasional campers. An effort has been made to see that visitors to the area are aware of the possibility of finding meteorites."



The eye end of the Lick 36-inch refractor with the filar micrometer attached. It rotates about the telescope's optical axis so its fixed wire may be set parallel to the position angle of a double star. The large spoked wheels (right) are manual declination and right-ascension clamps, and at upper left are the buttons of a pneumatic right-ascension clamp. At far left hangs the observer's control paddle, for electrically turning the dome, raising and lowering the observing floor, adjusting the windscreen, and controlling the telescope's slow motions. Lick Observatory photograph.

Visual Observing of Double Stars

CHARLES E. WORLEY, *Lick Observatory, University of California*

A CENTURY AGO, nearly all observational astronomy was visual, but today few professional astronomers look through their telescopes except while guiding. The human eye has been replaced by more effective light collectors, such as photographic emulsions and photoelectric surfaces. Yet in one field of astronomy – the observation of close double stars – visual work is still supreme.

The eye has two important merits as a light receptor: It perceives a star image very quickly, and hence can react to fleeting moments of good seeing; it is connected to an efficient computer – the brain – which permits a rapid analysis of results. These advantages make the eye superior to photography in the observation of double stars separated by less than about two seconds of arc.

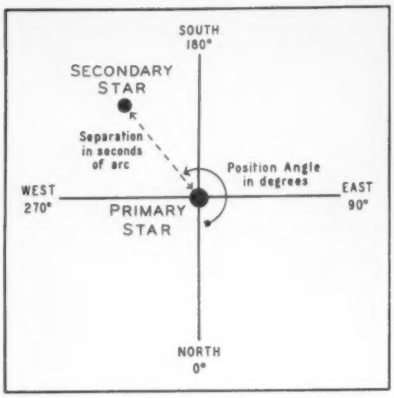
The comparatively long time required for an emulsion to record an image causes a slight blurring, due to the inclusion of moments of inferior seeing. In addition, because the images are of finite size, two of them close together on the plate tend to interfere with one another unpredictably, reducing accuracy. As image separation increases, however, photographic techniques become far more precise than visual observations, but most of the interesting and important visual binaries are very close ones.

An enormous amount of work by many astronomers has gone into the discovery and subsequent observation of double stars. Why all this effort? The main answer is that stellar masses, vital in our understanding of the structure and evolution of stars, can be found directly only by observing the orbital motion in binary systems, and visual doubles are best for this.

We may broadly divide binaries into four classes – visual, astrometric, spectroscopic, and eclipsing – depending upon the method needed to detect orbital motion. A visual binary is a pair of stars, revolving around a common center of mass in space, that can be seen as two stars in a telescope. All binary systems would appear as visual binaries were it not for the observational effect of distance. Astrometric, spectroscopic, and eclipsing binaries are detected by their variations in proper motion, radial velocity, and brightness, respectively.

Only in visual pairs and those eclipsing systems in which spectra of both stars can be seen are we able to determine individual masses. In many eclipsing systems, however, the components are nearly in contact and differ greatly from single, normal stars. An astrometric binary cannot give masses until the "unseen" companion is resolved visually. Spectroscopic binaries give only statistical masses for groups of stars. Thus the importance of visual systems in finding individual masses is clear.

Before a mass determination for a visual binary can be made, a long series of observations with suitable instruments is needed. Close pairs are measured with a micrometer, wider pairs on photographic plates. In either case we seek to determine the position of one of the



Above: E. E. Barnard's photographs of the visual binary Krueger 60 and a nearby field star. Note the revolution of the fainter component around its primary in the 12 years between the first and last pictures.

Left: Position angle and separation, indicated in this diagram, are a convenient way to record a double star observation. The brighter component is always chosen as the origin of co-ordinates.

components relative to the other. Measurements of close pairs are generally made in polar co-ordinates, taking the brighter component as the origin. The position angle, θ, is counted from north (0°) through east (90°), as shown in the diagram. The separation, ρ, between the stars is expressed in seconds of arc. Four settings usually are made for the position angle, and from two to four settings for the separation. These are repeated on three or four nights in one observing season to reduce accidental errors.

An experienced observer can measure from four to 12 or more pairs per hour, depending on the seeing, the difficulty of the pairs, and the quality of his equipment. Since most visual binaries have periods of decades or centuries, observations must be continued year after year in order to define an orbit. How often an individual system must be observed depends upon the rapidity of its components' relative motion.

After the companion has been observed over a long enough arc, an orbit can be computed. We almost never are able to observe directly the true form of the orbit, but only see an apparent orbit — the true orbit's projection on the celestial sphere. The *inclination* of the true orbit is the angle between its plane and the plane at right angles to the line of sight. If the inclination is 0°, the true and apparent orbits coincide, whereas if it is 90°, we view the orbit edgewise. Once the apparent orbit of a binary is known from observation, it is not difficult to compute the true one. Dozens of different methods, both geometrical and analytical, have been invented.

The diagram at lower left shows the apparent and true orbits of the bright double Castor. In this case, the orbital inclination is about 67°, so we observe a fairly narrow apparent ellipse. Rotating this ellipse through 67 degrees allows us to depict the true, unprojected orbit. Castor, whose period is about 500 years, has great current interest because the two stars are within a few years of their closest approach (periastron passage) and the relative motion is rapid. Since the separation of the components is about two seconds, and their visual magnitudes are 2 and 3, the pair is still easy to observe with a small telescope.

From the orbit computation of a binary star, we know the two quantities P, the period in years of one revolution, and a, the semimajor axis of the true ellipse, in seconds of arc. These allow us to calculate the total mass of the system in terms of the sun's mass as unity. We use the relation

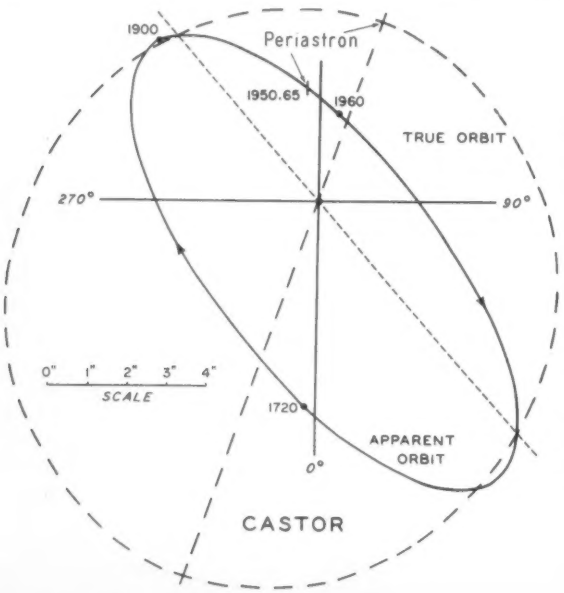
$$m_1 + m_2 = a^3/P^2\pi^3,$$

provided we know the parallax, π, of the binary, which depends on its distance from the sun. This information may be found by direct trigonometric measurement or estimated in some other way.

Notice that we still do not know the individual masses of the components, but only their sum. To apportion the total mass between them, a separate set of observations must be made to obtain m_2/m_1. This mass ratio can be found by referring the changing positions of one or both components to other, unrelated stars in the same field.

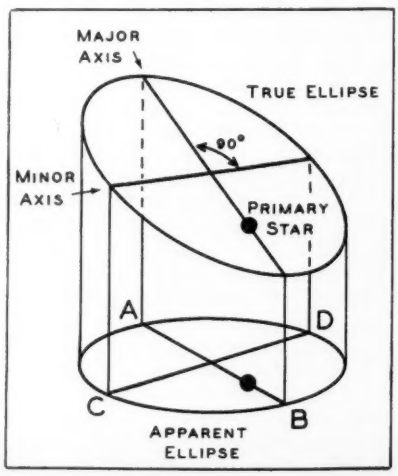
Clearly, it is a long road from the discovery of a new double star to the determination of its masses. There are about 53,000 known visual doubles, most of which are physical systems. Hundreds of thousands of measures of these pairs have been made. The periods of most of them are so long, however, that only 500 pairs — about one per cent of the total — have had orbits computed. Perhaps half of these orbits can be considered fairly reliable; the rest are poor determinations (usually premature).

Among several hundred systems with good orbits, only a fraction are close enough to us to permit good determinations of their parallaxes and mass ratios.

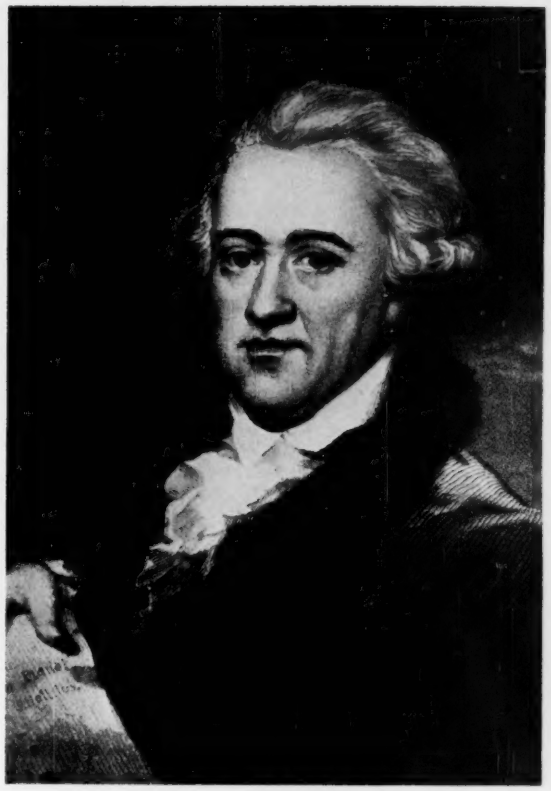


Left: The apparent and true orbits of Castor are shown by solid and broken ellipses, respectively. Represented by short dashes is the line of nodes, about which the apparent orbit is rotated to yield the true one. The line of long dashes is the major axis of the true orbit.

Right: The principle of the projection of a double star's true orbit upon the plane of the sky is visualized here. The vertical lines from A, B, C, and D, point toward the observer.



Left: The father of modern double star astronomy, Friedrich Georg Wilhelm Struve (1793-1864) was born in Germany, but spent most of his life in Russia. He was director of Dorpat Observatory from 1820 to 1838. Appointed by Czar Nicholas I to superintend construction of a new observatory at Pulkovo, he served as director there from 1839 until 1861.



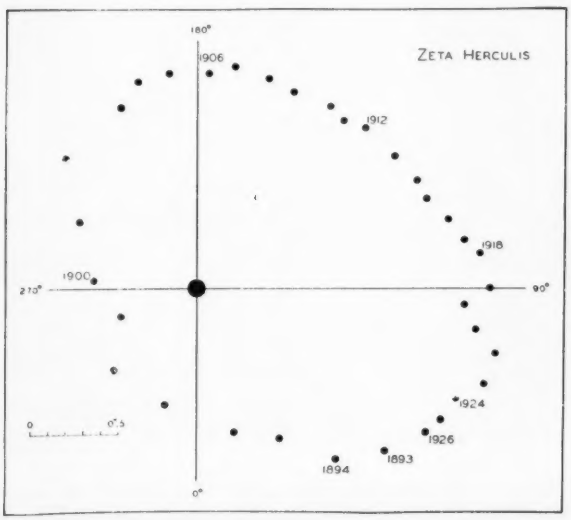
Right: Sir William Herschel (1739-1822) discovered hundreds of double stars while systematically searching with reflectors he had built himself. Originally a professional musician, he became famous as an astronomer by detecting the planet Uranus in March, 1781.

The number of binaries for which reliable individual masses have been found is fewer than 50 out of the 53,000 visual doubles! Most of these masses are of ordinary main-sequence stars, and astronomers await with great interest accurate mass determinations for giants, long-period variables, subdwarfs, and flare stars.

Even if we could not determine a single stellar mass, binary stars would still be of great importance. They form a large and probably a major portion of the stellar population. Consider the 30 nearest "stars." Of these 13 are multiple, having a total of 29 components, while only 17 are actually single. The situation is even more striking for the 30 brightest "stars" in the sky, as 15 are multiple and contribute 41 stars, while just 15 are single. And we probably have not yet found all the binaries among these objects.

In any discussion involving stellar distances, binary stars are apt to feature prominently. For some visual binary systems, it is not difficult to determine *dynamical parallaxes*. In the equation already given, if the orbital elements P and a are known or can be estimated, and if the total mass of the system is estimated from analogy with similar stars, we can calculate the parallax π. A modification of this method has been successfully applied to find distances for many hundreds of slow-moving pairs for which orbit computations are not yet possible.

Binary stars also play a role in studies of stellar evolution. Since the components of a system are almost certainly of the same age, a comparison of their physical characteristics provides important clues concerning evolutionary processes. Finally, binaries may be investigated for possible relationships among their orbital elements, or the orientations of their orbit planes relative to the plane of the galaxy. Such information also is linked to the origin and evolution of binary stars and of the galaxy.



The apparent orbit of Zeta Herculis is shown by positions of the companion, with respect to the primary, at approximately yearly intervals from 1893 to 1926. At present, the companion is near the location it had in 1893. This diagram shows the pair as seen in an astronomical telescope and has south at the top.

The first telescopic double star was reported by G. B. Riccioli more than 300 years ago, but for a long time astronomers thought the members of each pair were aligned by chance and were not physically associated, and little attention was paid to them. In 1781 Christian Mayer, of Mannheim, Germany, published a catalogue "of all double stars discovered up to now," which contained only 80 pairs. However, William Herschel in England had already begun to search for new doubles, and by 1821 had found about 800. It was he who first demonstrated from observation that some double stars were true binaries, with components revolving around common centers of gravity.

Herschel's pioneering work was soon followed by that of F. G. W. Struve, at Dorpat, Russia, who made the first double star measurements approaching modern standards of accuracy. In 1827 he published a catalogue containing 3,110 pairs, based upon a systematic survey begun in 1824 of the sky north of declination −15°. He looked at all stars brighter than about magnitude $8\frac{1}{2}$, but so rapidly did he work (averaging 400 stars per hour) that he missed many doubles among the 120,000 stars he examined. Struve's son Otto continued to search for doubles with the new 15-inch refractor of Pulkovo Observatory, and was able

to detect a total of 547 new pairs.

Many observers undertook the measurement of known double stars in the following years, one of the most successful being Baron Ercole Dembowski, who made nearly 21,000 measures at his private observatory near Naples, Italy. Another outstanding amateur was Rev. W. R. Dawes in England, who contributed long lists of exceptionally precise observations.

Little more was done, however, in searching for new double stars until the latter part of the 19th century. A new era began when S. W. Burnham of Chicago published his first list of 81 new pairs in 1873, all found with a 6-inch refractor in his back yard. He continued to find numerous doubles (despite a contemporary's warning that such discoveries could not long continue because almost all of the double stars had been found already!), and by the end of his career he had 1,340 to his credit, many of them close and important objects. After he became known for his double star work, Burnham had the use of many of the great telescopes of the United States. Yet, except for two short periods when he served as a professional astronomer, he continued until 1910 to earn his living as clerk of the Federal district court in Chicago.

Burnham's work indicated that many double stars remained undiscovered, providing the impetus for the great systematic surveys of this century. All of the catalogued stars brighter than magnitude 9.0 or 9.1 and north of −18° declination, plus some south of this limit, were checked by R. G. Aitken and W. J. Hussey at Lick Observatory. Between them they found 4,400 new double stars. A careful search of the southern sky was undertaken by R. T. A. Innes, W. H. van den Bos, and W. S. Finsen at the Union Observatory in South Africa. This survey added more than 4,000 new pairs before the end of 1931. It was continued by R. A. Rossiter and his collaborators at the Lamont-Hussey Observatory in South Africa, who found a further 7,500 pairs with the 27-inch refractor there.

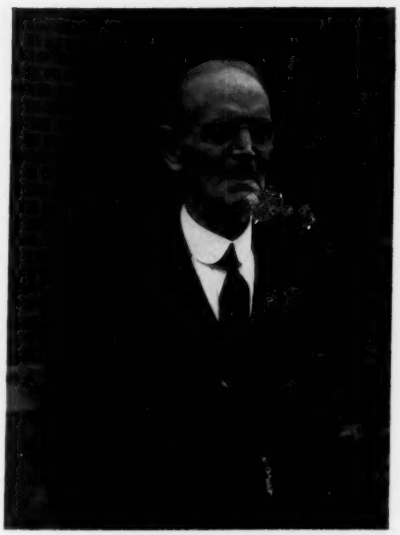
A snapshot of Sherburne Wesley Burnham (1838-1921) taken by Dorothy Wallace in 1908. His two-volume catalogue contains full histories of over 13,000 double stars.

In the meantime, observers in the Northern Hemisphere were busy finding new doubles, although these were generally fainter and wider pairs. More than 3,000 were discovered by the English amateurs T. E. H. Espin and W. Milburn, and a similar number in France by R. Jonckheere. Other astronomers found new pairs by examining star positions tabulated in the astrographic catalogues and noting those that were close together.

Not all double star discoveries are of equal significance. New companions to bright stars, peculiar stars, and the sun's neighbors are the most valuable. In recent years important contributions have been made by G. P. Kuiper and by Finsen. The former surveyed both the bright northern stars and those of large proper motion, finding a number of binaries that are noteworthy for their sizable parallaxes. His discoveries include BD −8°4352, the visual binary of shortest known period (1.7 years). Finsen uses an interferometer attached to Union Observatory's 26½-inch refractor in order to detect very close companions to the brighter stars in the southern sky.

New doubles are still being found, but at a much slower pace than formerly, and the great era of discoveries seems to be over. Cataloguing the very numerous known pairs has proved a major problem. In modern times, the first comprehensive listing was Burnham's *General Catalogue of Double Stars* (1906), which was intended to include all pairs north of declination −31°; it contained 13,665 systems. Large numbers of new discoveries soon made it out of date, and in 1932 Aitken published his *New General Catalogue of Double Stars within 120° of the North Pole*, "complete" to 1927. Although omitting many of Burnham's wider pairs, the new list contained some 17,180 doubles. About the same time, Innes published a similar register for the remainder of the southern sky. Today a new general catalogue, this time to include the entire heavens, is in preparation at Lick Observatory, and will contain some 53,000 pairs.

At the turn of the century, a dozen American astronomers were active double



Robert Grant Aitken (1864-1951). For four decades he used the 36-inch Lick refractor to measure difficult doubles. His book "The Binary Stars" (second edition, 1935) remains a valuable manual for double star observers.

star observers. At present, despite the growth of astronomy in this country, there are only two or three who devote their time to this kind of visual work, while the number of known double stars has increased four times since 1900. The major reason for this decline is that new and exciting branches of astronomy offer more opportunities for immediate rewards and significant discoveries. After all, the astronomer who observes a double star may have to wait a lifetime before he can derive its orbit, or, more likely, the fruits of his patient labor in a cold dome will be gathered by a later generation.

Yet, a double star measurement made with care has permanent value. If binaries in critical phases of their orbits are not observed, in many cases we may have to wait hundreds or thousands of years before the same stages recur. Keeping track of the very large number of binary systems thus imposes a heavy burden on the few astronomers who do this work, and there is at present room for the serious amateur to make a definite contribution in this field, just as he has in the past.

The requirements are not many: a good telescope, a micrometer (which is not too difficult to make), good eyesight, and a willingness to observe for several years. Many astronomers have found visual observing of double stars fascinating work, and there is always the genuine satisfaction that such observations have a long-range value to science.

ED. NOTE: In a subsequent article Mr. Worley, who is now at the U. S. Naval Observatory, will describe the construction and use of a filar micrometer for observing the position angles and separations of double stars.

Some Russian Radio Telescopes

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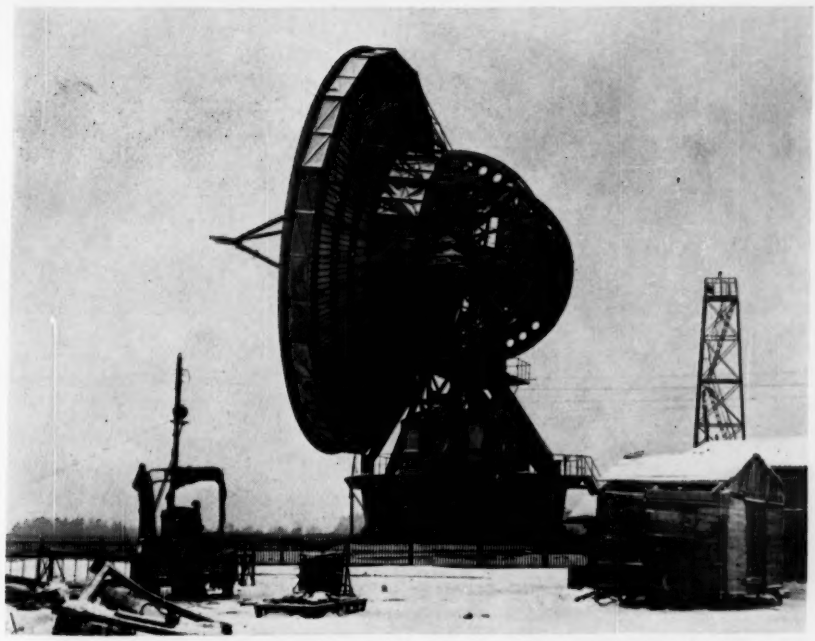
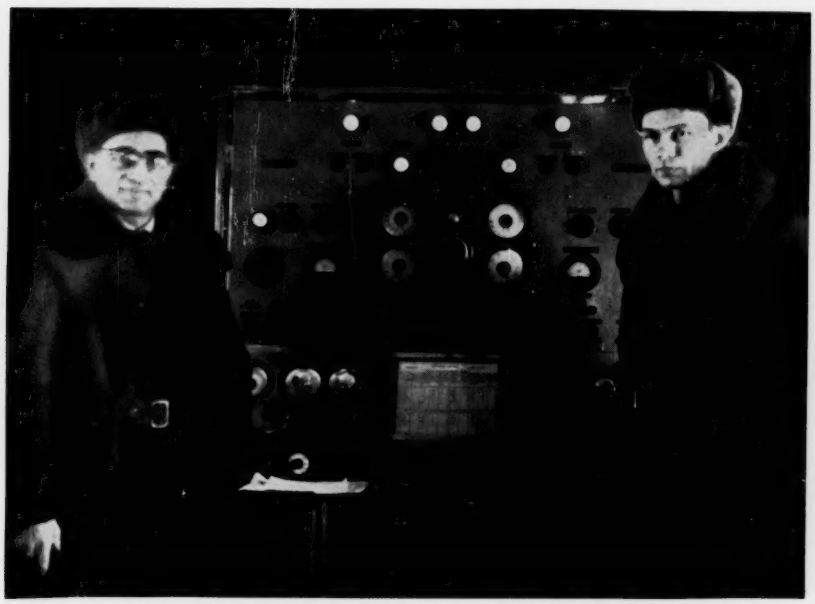


The principal instrument at the radio astronomy observatory of the Lebedev Physical Institute in Serpukhov, near Moscow, is this 22-meter precision paraboloid. Completed in 1959, the telescope has been used extensively in 8-mm. work. All photographs with this article are by G. W. Swenson, Jr.

IN NOVEMBER, 1959, an agreement was concluded between the Soviet Union and the United States providing for exchange visits of their scientists. As part of this program, V. V. Vitkevich, radio astronomer of the Lebedev Physical Institute of the U. S. S. R. Academy of Sciences, toured the United States for a month in the spring of 1960, traveling to many of the important radio astronomy installations in this country.

For the return visit, the authors were chosen by Detlev W. Bronk, president of the National Academy of Sciences, to go to the Soviet Union for two weeks, two Americans for that time seeming a fair exchange for the Russian's one month. Accordingly, we arrived in Moscow on January 21, 1961, after three days delay in London occasioned by bad flying weather and lost baggage.

We were taken in charge by an interpreter, who acted as guide during our entire stay. First we met with academy officials and were presented with our itinerary. This included visits to the Lebedev Physical Institute (Moscow), its radio astronomy station at Serpukhov, the Sternberg Astronomical Institute (Moscow), Pulkovo Observatory (Leningrad), and the Crimean Astrophysical Observatory (near Simferopol).



A. E. Salomonovich, left, and A. D. Kuzmin stand before the control console of the 22-meter paraboloid at Serpukhov. The console is in a cabin on the telescope's "azimuth" platform.

Near the city of Serpukhov, about 60 miles south of Moscow, is located a new research center of the academy. The first activity to be developed there is the Lebedev radio observatory, under the leadership of Dr. Vitkevich. Included in the impressive array of instruments at Serpukhov are two radio telescopes, which apparently rank as the most important in the country and, indeed, must be considered among the principal radio telescopes of the world.

The scientific and engineering staff has its headquarters in Moscow, but a substantial complex of laboratories and shops has been constructed at the field station, sufficient for much further expansion of radio-astronomy activity. In addition to Dr. Vitkevich, we conferred with radio astronomers Salomonovich, Kuzmin, and Panovkin; engineers Kalachev and Iliasov; and deputy administrator Kovalevsky.

The first major instrument to be completed was the 22-meter (72-foot) parabolic reflector, constructed under the supervision of Salomonovich and Kalachev. This is a very rugged and precise antenna with a focal length of 9.5 meters and a surface accuracy of the order of one millimeter. The beam can be pointed anywhere in the sky by means of an altazimuth mounting, equatorial-motion control being provided by an analogue computer. The shortest intended operating wave length is eight millimeters, at which the beam-width is slightly less than two minutes of arc.

The mounting of the reflector borrows

The east-west arm of the kilometer-long Mills cross at Serpukhov. Huge gears atop each tower, in the form of circular sectors, tilt the whole arm in declination. The reflecting screen had not yet been installed.

many of its design features from the heavy gun turret of a battleship. For azimuth motion, a gear about 10 meters in diameter is fastened to the interior of the turret and is driven by two synchronized direct-current motors (Amplidyne system) through cycloidal pinions. The gear consists of a circular channel into which are fastened "teeth," each a precisely machined cylinder about three inches in diameter with an eccentric mounting shaft to permit fine adjustment of position. Independently of this driving system is mounted another large circular gear-and-pinion set for sensing the position of the turret, connected with a position-programming selsyn unit in the control cabin. Tracking motion is controlled by the Amplidyne system through a differential gear, while fast motion (slewing) is provided by induction motors.

For the altitude motion, a 10-meter gear is mounted on each end of the horizontal axis. The gear construction and driving mechanism resemble those of the azimuth drive.

There are nine annular groups of parabolic aluminum plates in the reflector, each about 1.22 meters square, all plates in any ring being identical. A gap of one millimeter provides for thermal expansion of adjacent plates; they are mounted onto the sturdy structural frame by a myriad of intricate screw jacks that permit precise adjustments.

Originally it was planned to provide a hyperbolic secondary mirror at the focus of the reflector and to place the primary feed horn at the vertex of the paraboloid (a Cassegrainian system). However, this plan has been deferred in favor of mounting the feed horn on a four-legged support at the prime focus, together with a cabinet to house the radio-frequency components of the receiver or radiometer.

The co-ordinate converter and main control panel are housed on the "azimuth" platform in a cabin that also provides space for power-conversion equipment, receivers, and recorders. The altitude gears are carried by a horizontal tube $2\frac{1}{2}$ meters in diameter, inside which is a subsidiary control console for steering the instrument. A 5-inch optical telescope is mounted with its axis parallel to that of the parabolic reflector and its eyepiece accessible to an operator seated within the tube. This "finder" is useful for steering the radio telescope when it is used for high-resolution observations of visible objects. Another telescope, mounted coaxially with the paraboloid, is available for aligning the feed system at the focus.

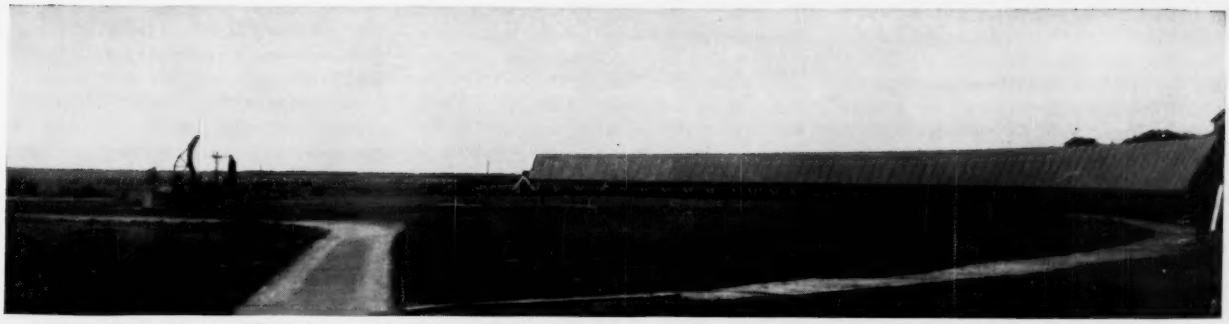
Since its completion in the spring of 1959, the 22-meter telescope has been used to map the 8-mm. radiation of the sun and moon, to measure the brightness temperature of Venus at 10 and 3 cm., and to compile a catalogue of discrete sources at 9.6 cm. At 8 mm. the beam-width is slightly less than two minutes of arc, and it is necessary to direct the antenna within half that angle of the desired point on the celestial sphere. A simple test during our visit demonstrated that the electronic co-ordinate converter could perform with this accuracy; presumably the rest of the system performs as well.

In surface accuracy and precision of pointing this impressive instrument has no competitors among reflectors of similar size. The only American instrument at all comparable is the 50-foot at the Naval Research Laboratory, but at 8 mm. it is severely limited by lack of a suitably precise mounting and the tendency of its surface to distort under stresses of wind and temperature.

Second of the two main instruments at Serpukhov is the one-kilometer Mills cross, an immense structure representing a very considerable investment. It is of rather straightforward design, having borrowed its principle from the original cross near Sydney, Australia, and its main structural features from the parabolic-cylindrical antennas constructed in the past several years by Martin Ryle and his colleagues at Cambridge University. Its great size, however, generates a host of new problems, some of which are being solved in ingenious ways and some by the application of sheer economic force.

A traditional Mills cross consists of two long, narrow, horizontal antenna arrays, generally set perpendicular to one another in a symmetrical pattern. Each arm of the cross produces a fan-shaped beam. Electronic "multiplication" of one beam by the other permits rejecting all signals except those arriving from the direction common to both, producing in effect a single pencil-shaped beam. The conventional plan is to have one arm extend from east to west so that its fan beam lies in the meridian plane. The other arm (north-south) then produces a fan intersecting the celestial sphere in the prime vertical plane. However, if the electrical phases of the individual elements in this arm are staggered progressively, its great circle will be inclined either to the north or south of the prime vertical. Thus, the resultant pencil beam can be moved north or south in the meridian plane by phase adjustment of the north-south elements.

Still incomplete is the north-south arm of the cross. Suspended from the steel posts will be a parabolic-cylindrical screen of wires. This arm will not be steerable, as is the east-west one.



This arc of 90 steel plates is a section of a paraboloid that focuses incoming radio waves on the parabolic cylinder at the left. Located at Pulkovo Observatory, this novel radio telescope is being used for solar studies. Details of the feed and of part of the mechanism used to orient the plates are shown on the following page.

The principal advantage of a Mills cross is that it gives very high resolving power at relatively low cost.

The Serpukhov cross has arms one kilometer long and is intended for use in the meter range of wave lengths. At a frequency of 100 megacycles per second, it can be expected to have in the zenith a beam of circular cross section with a half-power beam-width of 10 or 12 minutes of arc. At other altitudes the beam will be elliptical, as the beam-width in declination increases with zenith angle.

The arms of the cross are about 40 meters wide, resulting in a half-power width of about 4½ degrees in the wide dimension of either fan beam. Two advantages accrue from such broad arms. First, the relatively narrow beams produced materially reduce the possibility of trouble from unwanted side lobes in the over-all radiation pattern of the cross. Second, the total collecting area of the antenna is large, so the telescope has great sensitivity. The east-west arms, however, must be steerable in declination, adding greatly to the cost of the structure.

This east-west array consists of 37 steel towers, each slightly higher than 65 feet and surmounted by a parabolic truss in the north-south vertical plane. Each truss can be tilted in declination to point from the north pole to the southern horizon by a gear of approximately seven-foot radius, driven by a pinion and an induction motor. All 37 motors are synchronized by means of a start-stop servomechanism. The reflecting screen consists of a large number of parallel wires stretched from east to west along the row of trusses; thus, the entire antenna is east-west polarized.

The antenna array at the focus is to consist of a row of folded cage-dipoles of broad band-width and of input impedance about 600 ohms, with a flat, reflecting grid of wires suspended above them. There will be eight dipoles in each of the 36 bays of the east-west arm, a total of 288, with an average spacing between centers of 3.47 meters. This would appear to set the upper frequency limit of the radio telescope at about 120 megacycles per second, above which "grating side lobes" would become a serious problem. The transmission-line system will be of the "branching" or "corporate structure" type, in which the transmission-line distance from each dipole to the receiver is the same.

Beneath each tower is a roomy, subterranean, concrete chamber for housing preamplifiers and to serve as a junction and phase-adjustment point for the transmission lines. At the center of the cross is another instrument chamber, perhaps 30 by 50 feet in size, the main junction point for both arms.

Simpler construction was possible for the north-south arm, which need not be mechanically steerable. It consists of a parabolic-cylindrical screen of wires, polarized in the east-west direction in order to be consistent with the other arm, and suspended on an array of steel posts. The dimensions of the reflecting screen are also the same, but as the vertex of the parabola is nearly at ground level the phase center of the north-south arm is approximately 65 feet below that of the east-west arm. This will produce a complication not experienced with smaller crosses: It will be necessary to introduce a phase delay into the signal from the north-south arm, its value depending on the zenith distance.

From the state of construction in February this year, the east-west arm will be completed long before the other. In order to make use of this antenna before the entire cross is available, auxiliary apparatus is being built to permit the first arm to serve as one component of a long-baseline interferometer for the measurement of source diameters. The apparatus consists of a radio-relay link to transmit the information from the distant station to the receivers at the main antenna.

Since the first Mills cross was built in 1954, only a few instruments of this kind have been constructed, including the temporary 20-megacycle cross of the Carnegie Institution of Washington (with which the radio emissions from Jupiter were discovered) and the 19.7-megacycle cross at Sydney. Crosses of Christiansen arrays, in which the arms are "gratings" of widely spaced elements, have been built at Sydney and Stanford.

However, the Mills cross and variations of it seem about to assume greater significance in a new generation of radio telescopes having beam-widths measured in minutes of arc. These include the instruments being planned or constructed at Serpukhov, Bologna, Sydney, and by the Benelux group with headquarters at Leiden. Of these, the Serpukhov cross will probably be in operation soonest and may serve as an example for the rest. It can be expected to contribute greatly to radio astronomy, both as an engineering prototype and as a research instrument.

At Pulkovo, on the outskirts of Leningrad, is located the famous optical observatory. Here we were received by vice-director M. S. Zverev and conferred with radio astronomers Pariisky, Gelfreikh, Ikhsanova, Korolkov, Molchanov, Kaidanovsky, and others. In the past several years Pulkovo has become active in radio astronomy, particularly with respect to solar observations.

Many small radio telescopes have been provided for solar patrol and polarization observations. The principal instrument is of unusual and ingenious design. Its main purpose is to study the sun at wave lengths of 3, 10, and 30 cm., but it is also useful for some of the stronger discrete sources and the galactic center.

The general philosophy of the large Pulkovo radio telescope is based upon the fact that the accuracy of a parabolic reflector's surface is limited to about 1/20,000 of its diameter for instruments of moderate size. This is the case with the Serpukhov 22-meter paraboloid. For larger sizes the situation is worse. It can be reasoned that the limiting beam-width obtainable with a single reflector is about one minute of arc under the best conditions.

Yet, geodetic surveying techniques permit measurement of distances and angles to one part in a million. Thus, if we build a faceted surface, each facet having a surface accuracy of a millionth part of the diameter of the entire reflector, and each positioned on the ground with like precision, the over-all accuracy should be much greater than that obtainable in one large reflecting surface.

The long-established use in radio astronomy of interferometers, consisting of interconnected but widely separated an-

tennas, can be interpreted as an application of the above principle. In the Pulkovo instrument, however, a large number of individual reflectors are arrayed in such a way as to have a single focal point.

Ninety flat steel plates, each three meters high and 1½ meters wide, are arranged on an arc of a circle of radius 100 meters, having a chord length of 140 meters. Each plate has an adjustable mounting for precise positioning in altitude, azimuth, and radial distance from the center of the circle. Now imagine a paraboloid of revolution with its axis vertical, its vertex below the surface of the earth, and its focal point at ground level. All the plates in the array can be made tangent to the imaginary paraboloid, so that a plane wave arriving from the zenith will be reflected by the plates to the focus.

By means of the adjustable mountings, the plates can be made to simulate sectors of other paraboloids whose axes have different orientations but whose foci are all at ground level. For directions other than the zenith, the simulated arc will be elliptical. With the freedom provided by the mountings, it is possible to steer the principal beam of the radio telescope between the zenith and the southern horizon and 35 degrees in azimuth on either side of the south point. In so doing the position of the focal point moves along a straight north-south line 50 meters long. Not all of the plates are in use at any one time; for meridian observations about 70 are used, and as few as 50 at other times.

The feed system consists of a parabolic-cylindrical reflector and a horn. As the flat reflecting plates provide no directivity in the declination co-ordinate, the beam-width in this direction is determined by the height of the parabolic cylinder. In effect, the array of plates focuses the wave in one dimension, the parabolic cylinder in the other. The latter's focus is that of the entire instrument, where a horn or dipole is the primary radiator (or receptor) of the system.

To change the direction of the beam, it is necessary to manipulate each of the flat plates into position and to move the cylinder and horn to the proper place on the line of foci. The latter two elements move along a railway. Although we did not observe this adjustment operation, we estimate that two men could establish a new beam direction in two or three hours.

At 3 cm. the horizontal beam-width is one minute of arc at the southern horizon, while the vertical beam-width is about 35 minutes when the beam is 12 degrees above that horizon. But the vertical beam narrows rapidly at higher altitudes, until at the zenith it is about six minutes. The horizontal width is much less dependent on altitude. The beam-widths at 10 and 30 cm. are proportionately greater.

Because each plate coincides with the imaginary parabolic surface at best only at the points of an elliptical locus on the plate, there are periodic errors in the surface that must cause substantial side lobes, depending on wave length and the widths of the plates. These lobes would be a serious handicap to studying fainter sources, but the Pulkovo instrument is not intended for such work.

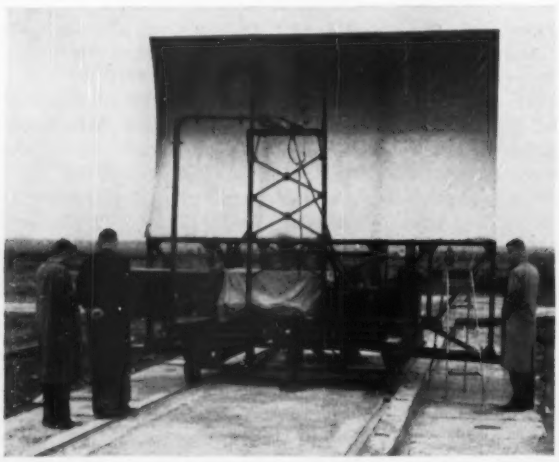
The predicted performance of this telescope was verified experimentally, using target transmitters and cosmic sources. Ratios of effective collecting area and actual projected surface area of about 45 per cent were obtained, consistent with the results usually achieved with good parabolic reflectors. This instrument was very carefully planned, its performance established in great detail by theoretical studies. The mechanical components are rugged and precise, their design supervised by engineer Kalachev, who also constructed the two Serpukhov instruments. His skillful and meticulous work is evident in all three and contributes in great measure to their success.

To obtain a narrower beam at 30 cm., two 12-meter parabolic reflectors are being set up 100 meters apart, with the center of their base line 115 meters from the center of the main Pulkovo instrument. They will operate as a total-power interferometer, whose radiation pattern multiplied by that of the main telescope will produce a beam-width of only one minute of arc. Although this horizontal beam-width will be comparable to that otherwise obtained at 3 cm., somewhat worse side lobes are to be expected with the new arrangement.

We were informed that the large Pulkovo radio telescope cost $150,000 at the official rate of exchange. In the United States, construction and engineering costs would run several times that figure. Even so, extremely good resolution has been obtained at very moderate expense. Certainly no existing antenna of the single-paraboloid type can achieve corresponding resolution at a 3-cm. wave length.

At the Crimean Astrophysical Observatory we were received by Prof. A. B. Severny. The observatory as a whole has specialized in solar work, and the radio work has been mostly in that field, but a 22-meter reflector is being planned for nonsolar observations. During our visit the observatory's 102-inch optical telescope was being adjusted and preparations were being made for the February 15th eclipse. Dr. and Mrs. Harold Zirin, of the High Altitude Observatory in Colorado, who had been living at the observatory for some months, welcomed us and acted as our guides.

We left the Soviet Union impressed with what has been achieved in special types of radio telescopes. Each of the three principal instruments described here represents an ingenious contribution, and reveals solid support financially and in terms of personnel. At Serpukhov, for example, there was said to be a staff of 450, and the Lebedev and Pulkovo groups are rather large compared with similar staffs in the United States.



This parabolic cylinder and horn arrangement at the focus of the Pulkovo instrument has been replaced by an off-axis feed system in which the horn radiates upward into the parabolic cylinder.

The adjustment mechanisms of the steel reflecting plates. The pictures of the Pulkovo instrument were taken by Dr. Swenson on an earlier trip to the Soviet Union, in 1958.

OBSERVING THE SATELLITES

Transit IV-A

THE fourth successful launching in the Navy's program to develop an accurate, world-wide, all-weather navigation system began at Cape Canaveral, Florida, at about 4:23 Universal time on June 29th. Inasmuch as lifting the 175-pound Transit IV-A payload into its nearly circular orbit did not utilize the full capability of the Thor Able-Star vehicle, two smaller instrumented packages were also carried aloft.

Unlike its spherical predecessors, Transit IV-A is a 16-sided 43-inch drum, standing 31 inches high. Its most important new feature is a radioisotope-fueled thermoelectric power supply called Snap 3. (The name comes from the initial letters of "System for Nuclear Auxiliary Power.") The 4.7-pound unit should provide more than 2.5 watts of power, from heat generated in the gradual decay of plutonium-238, for at least five years.

Before this device was included in the payload, elaborate destruction tests were made to show that the plutonium would be retained in its capsule under any foreseeable combination of misadventures that would return it to earth. Only a portion of the satellite's power requirements are furnished by Snap 3; solar cells and nickel-cadmium batteries are also used.

The importance of a long-lived, reliable power supply, simple and lightweight, is well illustrated by experiences with the preceding navigation satellites. Transit I-B ceased transmitting on July 11, 1960, after 89 days of operation, when a thermal switch that was designed to protect the storage battery from being overcharged by the solar cells opened improperly. In Transit II-A, the same switch opened permanently; this time its circuit could be shorted upon ground command, but was then left without protection against overcharge. Thus, after 129 days in orbit, when for a time Transit II-A passed into continuous sunlight on October 28, 1960, the battery was ruined, and now transmissions are heard only when the satellite is in sunlight. The other successful launching, III-B, had a low perigee and stayed in orbit only 36 days, transmitting all the while.

Despite the power-supply problems, and the fact that earlier orbits have been more eccentric than planned, the Transit program has already achieved considerable success. Some key results have recently been summarized by the program director, R. B. Kershner, of Johns Hopkins University's Applied Physics Laboratory.

As previously told in this magazine (June, 1960, page 461, and August, 1960, page 84), the Transit navigational system determines the location of a vessel by measuring from shipboard the Doppler shift of radio signals transmitted from an orbiting satellite. The frequency of these transmissions must be held constant within very narrow limits, as any drift would be ascribed to a Doppler effect. A drift of only one cycle in a 100-megacycle signal during a Transit satellite's crossing might amount to an error of a mile in the ship's position. Experience has now shown that in a full hour the frequency changes by less than 0.1 cycle.

Transit III-B has successfully rebroadcast its own orbital parameters by binary-coded phase modulation, and has transmitted time signals without interfering with the Doppler measurements.

There have now been processed an enormous number of Doppler measurements at fixed ground stations, chiefly of Transit I-B and II-A. Tracking results show that the satellite position can be predicted 12 hours ahead to within a few tenths of a mile, if drag effects are not too pronounced. As far as fixed observing sites are concerned, one limitation upon the accuracy of the Transit navigational system is that widely separated relative locations upon the earth's surface, the earth's shape, and its mass distribution are not yet known with enough precision. The Transit method requires better geodetic information than we now have, and, along with other satellite programs, is helping gain such data.

One of the two other payloads sent aloft with Transit IV-A was a Naval Research Laboratory experiment for monitoring X-rays from the sun. Known both as Solar Radiation III and as Greb III, the 55-pound sphere is 20 inches in diameter, and has six solar-cell patches, each nine inches in diameter. Its predecessor, Greb I (II failed to attain orbit), carried in addition two sensors, one for solar ultraviolet. But it failed to show any significant change, even on August 6, 1960, when an intense flare caused a radio fade-out, together with a large increase in X-rays, monitored from orbit for the first time by that satellite.

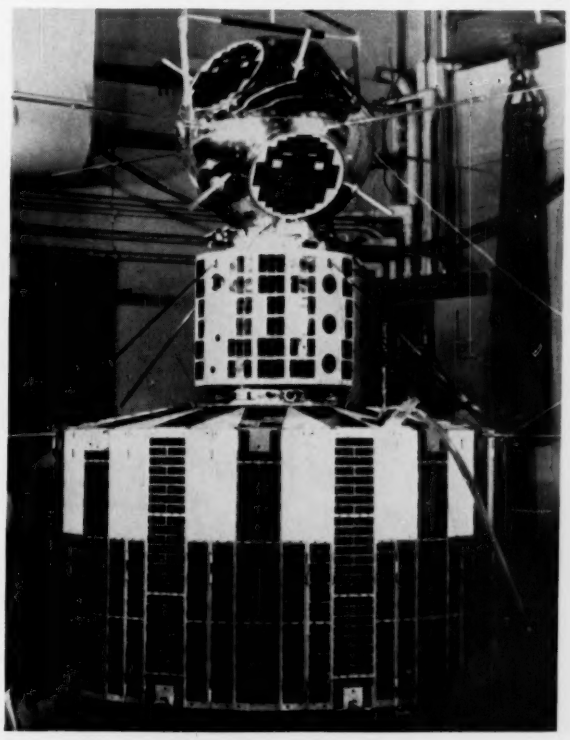
Greb III has two X-ray sensors, extending the range of measurement to the lower intensity levels expected as the sunspot cycle wanes. The satellite is planned to function for a year.

At launching, the remaining instrument package was mounted between the other two inside the Able-Star's shroud. Named Injun, this drum-shaped payload weighs about 40 pounds. It was developed at the State University of Iowa under the direction of J. A. Van Allen, for investigating the belts of trapped radiation that bear his name. Its purpose is to seek the relationship of the airglow and aurora to the flux of charged particles.

Discoverer XXV

CONTINUING improvement in the performance of the Discoverer vehicle, particularly of the recently altered Agena-B second stage, was a major objective of the 25th launching in this series. Changes in the guidance, propulsion, and stabilization systems were tested with this shot, which started off in heavy fog from Vandenberg Air Force Base, California, at 23:02:52 Universal time on June 16th.

Eight days earlier the 24th launching, with a similar mission, became the series' seventh failure to attain orbit. It returned only four minutes of telemetry



Transit IV-A, with its companion payloads, was put in orbit on June 29th. The sphere at the top is Greb III, designed to measure solar X-rays. In the middle is Injun, an experiment to record the flux of charged particles responsible for the aurora and airglow. Solar cells (the rectangular elements covering much of the payloads' exteriors) extract energy from sunlight for supplementary power. The Transit series of satellites is sponsored by the U. S. Navy, its purpose being to provide exact navigational positions regardless of surface weather. Johns Hopkins University photo.

before plunging into the Pacific. Discoverer XXV, however, successfully entered orbit, and the stabilization system of the 2,100-pound Agena consumed its supply of reaction gas slowly enough to permit its managers to leave it in orbit a second day before signaling release of the 300-pound capsule.

Two factors dictate when a recovery attempt will be made in the Discoverer series: performance of the satellite, and the weather anticipated in the recovery zone. The 55th Weather Reconnaissance Squadron flies observation planes, each with a crew of eight, over the recovery area for about a week before each Discoverer launch. They have now logged 6,000 flying hours on some 500 flights covering an over-all distance of 1½ million miles in a vast area surrounding Hawaii. Winds and clouds affect mid-air snatches of descending capsules, and ocean swells are a factor when a capsule needs to be pulled from the water, as was the case with Discoverer XXV.

At about 1 o'clock UT on June 19th, the re-entry sequence began over Alaska, but the capsule came down about 230 miles north of the predicted impact point. One of the patrolling aircraft spotted it floating in the Pacific Ocean about 380 miles northeast of Hawaii. Soon three scuba divers of the Air Rescue Service parachuted into the water from an SC-54 Rescuemaster plane, brought the capsule aboard a rubber life raft, and rode out the night with it until the destroyer U.S.S. *Radford* picked them up.

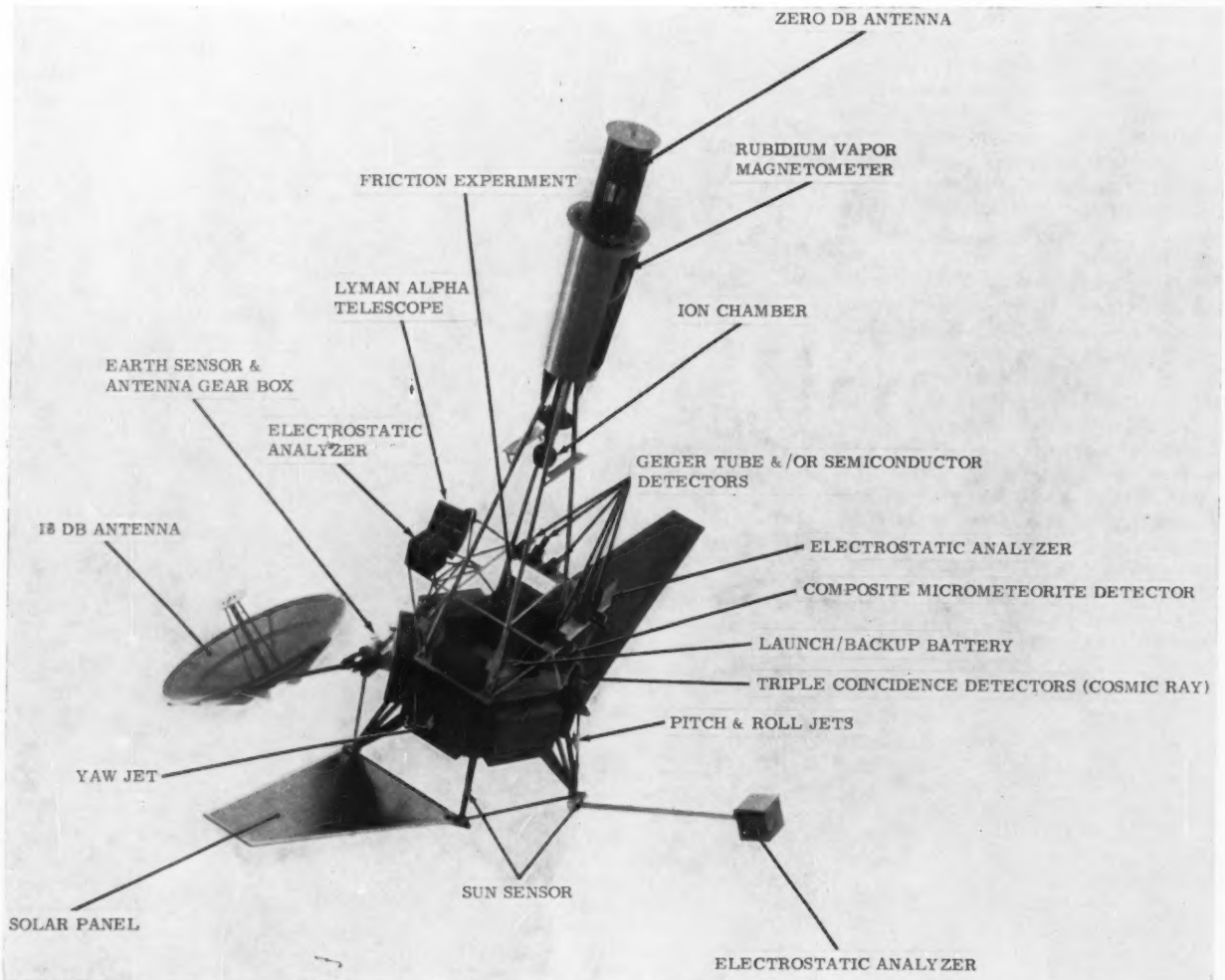
This was the fifth Discoverer capsule to be recovered for examination. Its payload is expected to reveal the effect of space environment upon an assortment of metal specimens: magnesium, titanium, iron, nickel, yttrium, cadmium, gold, and bismuth. Three geiger tubes monitored cosmic rays, and a micrometeorite experiment was aboard.

The Ranger Project

THE outstanding capability of a new type of spacecraft will be to establish itself in any desired orientation while on far-ranging missions. The first flight model in this series, Ranger I, is now being readied for launching by an Atlas-Agena-B booster from Cape Canaveral, Florida. At least three of the later shots in this program will attempt to drop seismometers onto the surface of the moon, but for the first two firings, to test many design innovations, lunar impact is not planned.

In the Pioneer program, the National Aeronautics and Space Administration's earlier series of ventures into deep space, the probes were all merely spin-stabilized, incapable of any mid-flight maneuvers, except for the unsuccessful Atlas-Able probes of November 26, 1959, September 25, 1960, and December 15, 1960. And although these three were planned to develop forward or backward acceleration in mid-flight upon command, the force was to be constrained along a particular direction that would be established much earlier, at the instant of third-stage burnout.

A spacecraft of the Ranger series, on



A model of the Ranger spacecraft that is being readied for flight later this year by California Institute of Technology's Jet Propulsion Laboratory. Ranger will be 12 feet long, approximately five feet in diameter at the base, and will weigh between 600 and 800 pounds. JPL is in charge of research for the National Aeronautics and Space Administration's program of exploration of the moon, planets, and interplanetary space.

the other hand, is to be capable of setting up its own reference attitude. From this it can temporarily achieve any other selected orientation. Thus, for a corrective or terminal maneuver, the thrust may be aligned along any desired direction; or a program of direction-sensitive scientific measurements may be undertaken.

Discoverer satellites, orbiting close to earth, have long been capable of attitude control, as have many of Russia's satellites and deep probes. Now Ranger is entering the weight class where this kind of sophistication becomes possible. The 700-pound craft will be about 11 feet long in some models.

When attitude-stabilized in flight, its narrow end will be pointed toward the sun, so that the two panels of solar cells, each extending outward nearly six feet from the large hexagonal base, will be perpendicularly illuminated without shadows from the superstructure. Also, the Ranger will be rolled about the sun-directed axis of symmetry until its earth sensor fully stabilizes the orientation, with the four-foot parabolic antenna aimed toward the earth.

Though a number of details may be changed before the Rangers actually fly, the following notes come from various accounts by engineers of Jet Propulsion Laboratory, California Institute of Technology, who are managing the Ranger program for NASA.

There are two simple sun sensors, arranged for pitch and yaw control. In each a vane will cast a shadow equally upon two matched cadmium selenide photoconductors, provided the craft is properly pointed toward the sun; the shadow will fall unequally if the spacecraft is oriented wrongly.

The earth sensor is a triad of photomultipliers (with variable gain to compensate for vastly changing distance from Earth) arrayed behind masks that divide the light reflected from Earth equally about a central plane when properly oriented. They will also show at what pitch angle the directional antenna should be pointed, though radio control is also available for this function.

Three gyroscopes, each connected to measure rate of rotation about one of the axes of the vehicle, can be switched into the control system to permit a maneuver away from the reference orientation, or to hold temporarily an attitude in which the light-sensor outputs are not in balance. The duration and angular rate of such a turn about a given axis are commanded from the earth, and then the vehicle is held steady by a null signal from the gyros.

A supply of nitrogen in an eight-inch tank, under an initial pressure of 3,000 pounds per square inch, will furnish the orienting thrust. Electrically operated valves will permit tiny amounts of the gas to escape from any of the craft's jet nozzle pairs. The supply of gas and the operating lives of the rate gyros limit the system's lifetime to two or three months — long enough for accomplishing Ranger's missions. During that time the spacecraft's attitude can be controlled within 0.1 or 0.2 degree.

To launch a Ranger into the standard departure path that will fit nearly all early assignments, the Agena B will be placed initially in a "parking" orbit. Then its engine will be started again to bring the speed close to escape velocity. In the first shot, the trajectory will have a nominal apogee of 685,000 miles, but a perigee so low that the satellite might not last out its first or second passage near the earth. The period for such an orbit is roughly 7½ weeks, nine-tenths of which is spent at distances greater than the moon's. A later Ranger mission will pass near the moon, with the results of a lunar encounter relatively uncertain.

Among the early Ranger experiments, the Lyman-alpha telescope demonstrates the value of controlled orientation. Surrounding the earth is a cloud of neutral hydrogen gas that is caused by the dissociation of atmospheric water vapor by sunlight. This cloud begins at altitudes of about 50 miles and extends, perhaps, tens of thousands of miles into space, forming the main constituent of the earth's exosphere. The hydrogen radiates in the far ultraviolet at 1216 angstroms, the wave length of the Lyman-alpha line, and at shorter wave lengths.

The Ranger-borne telescope will provide a crude picture of the earth and its exosphere in the wave length region 1050 to 1350 angstroms. A 10-inch f/0.6 magnesium mirror will scan a rectangular pattern, concentrating the radiation on a nitric oxide gas ionization chamber with a lithium fluoride window. This instrument, developed by the Naval Research Laboratory and Jet Propulsion Laboratory, will obtain valuable information on the worldwide extent of auroral activity, in addition to its prime purpose of recording the hydrogen radiation.

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MORE ABOUT THE EARTH'S CLOUD SATELLITES

(Continued from page 63)

The rarity with which this set of conditions is met helps explain why the clouds had previously escaped recognition. This May, Dr. Kordylewski visited Sonneberg Observatory in East Germany, where many thousands of patrol photographs have been made with fast cameras for variable star studies. It turned out that not a single photograph from 1928 to 1960 had been taken covering a libration point when the moon was out of the sky!

Even when a photograph is correctly centered, the clouds' very low surface brightness poses special difficulties. The problem is somewhat akin to that of recording the Sculptor system — a large nearby galaxy of extremely slight surface brightness. It shows as a barely recognizable smudge on long-exposure plates taken with fast, small cameras; medium-sized telescopes cannot photograph it, but a very large reflector can record its individual stars.

Dr. Kordylewski's efforts to photograph the earth's cloudlike satellites were unsuccessful until this spring, when he recorded them on March 6th and April 6th with an f/1.5 camera of 50-millimeter focus. The films covered an area of 25 by 37 degrees, and were exposed for 13 minutes.

With such a camera, vignetting causes the sky fog to be densest at the center of the picture; hence special precautions had to be taken to insure that a cloud satellite was actually observed. The program for each night called for four exposures, taken with the libration point in different locations relative to the center of the field. Nine of these films were measured with the recording microphotometer of Wroclaw Observatory, and for each, contour lines of equal photographic density were determined.

The libration clouds could be recognized by deformations of the contour lines, allowing their positions to be measured. On all exposures of March 6th in Leo and April 6th in Virgo, two clouds about eight degrees apart were identified, in approximately the same locations relative to the L_5 point on both nights. A check was given by the absence of such images on a photograph taken March 8th of the same area in Leo, when the libration point had moved on into Virgo.

Not only should these two remarkable objects near the L_5 point be reobserved, but the other libration point, 60 degrees ahead of the moon, needs careful examination. For several months neither will be well placed for watchers in the Northern Hemisphere. The L_4 point becomes accessible October 18th for three days, moving from south-central Pisces into Aries. Again, circumstances will be favorable for northern observers November 16-19, when the L_4 point moves from the Cetus-Aries border near Pisces through the Hyades. However, the L_5 region will not be favorably located until next January. The Smithsonian Astrophysical Observatory is planning to make photographic observations with its network of fast Baker-Nunn tracking cameras when the time is right.

Dr. Kordylewski points out that a new search with very large telescopes will be worth while in order to find individual meteoroids in the libration clouds. Such members could be situated as far as 10 degrees from the libration points. He also emphasizes the opportunity for amateur naked-eye observations, especially by those who have had experience with the gegenschein.

Amateur Astronomers

NORTH-CENTRAL REPORT

THE University of Illinois at Urbana was the site of the 15th annual convention of the Astronomical League's North-Central region. Conducted by members of the college astronomical society, the program was enjoyed by 115 persons, representing 24 societies in seven states, on April 28-30.

Prior to official opening of the meeting, delegates toured the university's nuclear reactor, guided by members of the physics department. A field trip to the school's radio telescope near Danville concluded the two-day session.

Twelve talks, covering a wide range of theoretical and practical subjects, comprised the adult and junior paper sessions. High-magnification photographs of Echo I, a planetarium for Peoria, the constellations in color, solar corpuscular emission and the aurora, projects of the Key Biscayne Astronomical Association, and photometric instrumentation were among the topics presented.

During the business meeting the following regional officers were elected: chairman, H. F. DaBoll, Argonne Astronomy Club; vice-chairman, Richard E. Wend, Milwaukee Astronomy Club; secretary-treasurer, Jose Hernandez, St. Paul Telescope Club; and regional representative, Mrs. R. Buckstaff, Oshkosh, Wisconsin.

JOSE HERNANDEZ
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St. Paul 3, Minn.

SOUTH SHORE MEETING

SOME 100 amateur astronomers attended a day-long gathering sponsored by Massachusetts' South Shore Astronomical Society at Norwell Grange. Though the weather was threatening, it did not hamper the enthusiastic discussions of this "little Stellafane" meeting on June 24th.

After early-afternoon registration and the setting up of telescopes, informal talks were given. The first was by Ronald R. Willey, Jr., East Hartford, Connecticut, who considered in great detail the optical aberrations of various telescope designs. Then, following a motion picture on the Nike-Zeus antimissile missile, Franklin Torney, Jr., of Newton, Massachusetts, told how to choose a telescope to meet observing needs. Finally, Ralph W. Walker, Rochester, Massachusetts, described the construction of his observatory (SKY AND TELESCOPE, October, 1960, page 206).

In a very close telescope contest, with Mr. Torney acting as judge, Jim Qualter of the South Shore society won first place with a beautifully finished 6-inch f/7 Newtonian reflector. G. Sauvageau, Amateur Telescope Makers of Boston, took second place with an 8-inch reflector, and Walter A. Singer of the same club came in third with the instrument shown here.

Walter A. Singer (right) of Saugus, Massachusetts, answers queries about his 6-inch f/7.5 Newtonian reflector asked by Stanley Lemon of Weymouth.

After dinner, Charles H. Smiley of Brown University spoke on Mayan astronomy. Then a star party was held at nearby Norwell High School, with fair observing conditions.

MID-STATES CONVENTION

VIEWS of Venus through the Morrison Observatory's recently restored 12¼-inch Clark refractor (see page 106) highlighted the convention of the Astronomical League's Mid-States region. Observing conditions were excellent for the 100 delegates at Fayette, Missouri, June 16-18.

Noteworthy instruments at the meeting included two 4-inch Clark refractors, the Morrison 6-inch transit circle, two Maksutov telescopes, and one 4-inch schiefspiegler. One of the Maksutovs was the subject of a talk by Lauran Kilmer, Tulsa, Oklahoma, while the schiefspiegler was demonstrated by Robert E. Cox, O'Fallon, Missouri. This instrument was used at 100x on a low, setting moon, and after midnight showed detail on Jupiter and Saturn at 240x.

Other subjects discussed were color astrophotography, by Robert Sandy, Kansas City; radio studies of meteors, by Edward Haskell, Tulsa; and instruments for lunar and planetary observing, by Mr. Cox. At the informal banquet, John Schopp of the University of Missouri talked about stellar evolution.

On Saturday morning, June 17th, the Central Missouri Amateur Astronomers dedicated their new observatory with its 12½-inch reflector. Its mounting was donated by Kaiser Aluminum and Chemical Co., Mexico, Missouri. The new instrument was first used that evening.

+++ AMATEUR BRIEFS +++

Star parties of the Eastbay Astronomical Society in Oakland, California, are overnight camping affairs on Mount Diablo, to which all amateurs in the area are invited. $1.00 covers breakfast for a hungry stargazer. The last party this summer is planned for August 19th.

The Astronomy Club of Akron, Ohio, expects to mount an 8-inch f/11.4 Newtonian reflector on the lawn of the Akron airport's administration building. In such a prominent spot, the telescope will attract new members to the group and be available for some individual observing projects.

The science of satellite tracking as practiced by Suncoast Moonwatch in St. Petersburg, Florida, was not exactly advanced one evening, according to their newsletter. No less than five satellites were to be tracked in a period of two hours, with an awesome battery of telescopes ranging from one to 12 inches in diameter. When the first four satellites had failed to appear, the chilling realization came to the team leader that all the calculations were for the following evening!

Current computations of the longevity of some of the many artificial earth satellites are reported in another Suncoast Moonwatch newsletter: Explorer I, the first United States satellite, 5½ years; Vanguard I, 200 years; Tiros I, 50 years; and the Echo I rocket, 4,000 years.

Amateur astronomers who read Italian will be interested in the *Bollettino* of the Ticinese Astronomical Society, a section of the Swiss Astronomical Society. The first issue, published in Lugano, Switzerland, in June, contains 92 pages on the group's activities, observations of the February total eclipse, and studies of Jupiter.

Active junior astronomers in Shreveport, Louisiana, enjoyed the publicity of a feature article in *Shreveport Magazine*. Their most ambitious plans are to give a planetarium and observatory to the city. One fund-raising project was a star party that attracted about 1,000 persons at 30 cents apiece, even though it was raining in several parts of the city!

G. B. C.

THIS MONTH'S PROGRAMS AND CONVENTIONS

Hershey, Pa.: Middle-East region, Astronomical League. Cocoa Inn, August 19.

Long Beach, Calif.: Western Amateur Astronomers. Lafayette Hotel, August 24-26.

Shreveport, La.: Shreveport Junior Astronomical Society, 7:30 p.m., Centenary College science hall. August 19, Ralph Worley, "Let There Be Light."

Springfield, Vt.: Stellafane. Breezy Hill, August 12.

ASTRONOMICAL SCRAPBOOK

Beginnings of the Space Age

ASK ANYONE what was the first application of rocketry to astronomical observation, and the answer you hear will probably involve Luniks and Pioneers, or perhaps study of the ultraviolet solar spectrum by V-2's fired from White Sands in the late 1940's. All of these replies happen to be wrong in time by more than a century.

To win a bet on this, a good referee is J. G. F. Bohnenberger's classic manual of practical astronomy,* whose second edition appeared in 1852. He is speaking of methods of determining geographical longitude, which depend, then as now, on comparing the local times at two places of some sharply defined event recorded at both stations. Bohnenberger tells:

"Rockets are admirably suited for finding the difference of two meridians. To avoid using intermediary stations between two rather distant points, . . . one needs rockets that ascend 8,000 or 9,000 feet, exploding at this level, and which can be seen from a distance of about 120 miles. If these signals are launched from a mountain 5,000 or 6,000 feet high, they can be seen quite well at a distance of 140 miles, making it possible to determine directly the longitude difference of two places 250 to 275 miles apart. At peak altitude, the rocket automatically fires a charge of half a pound or one pound of gunpowder, forming a momentary brilliant flash of light that can be timed with great certainty."

Rockets were actually used in this way, and Bohnenberger reports in detail a determination on May 6, 1822, of the longitude difference between Vienna and Neustadt, Austria. Three rockets were launched that evening, from which it was deduced that Neustadt lay 33°.02 of longitude west of Vienna.

This early use of rockets can properly be regarded as a true forerunner of such achievements in today's astronomical geodesy as determining the earth's shape from Baker-Nunn camera photographs of Vanguard satellites. Perhaps the advance has been more in technology than in scientific imagination.

Currently, plans for a manned observing station on the moon are assuming practical importance, as the likelihood grows of a landing there during the next decade. As early as 1837, W. Beer and J. H. Mädler made a study of the possible advantages of an astronomical observatory on the moon, which is summarized on pages 22-24 of their selenographical treatise, *Der Mond*. Some of their thoughts have a modern ring, such as the convenience of being able to watch the development of sunspots uninterruptedly over a 350-hour interval, the length of daylight on the moon.

However, in 1837 it was not known that the lunar atmosphere was virtually nonexistent, and the German astronomers supposed that fainter stars would be invisible from the nearer side of the moon, because of the glare of the earth, even when the sun was below the horizon. The advantages that they predict for astronomical work from the averted hemisphere apply also to the side that we see.

One point mentioned by Beer and Mädler is worth consideration even today — an increased difficulty in making precise measurements of altitudes of celestial objects. This is a consequence of the lunar terrain being relatively more rugged than the earth's, causing large deflections of the vertical as indicated by a plumb bob or other device used to show the direction of gravity.

Quite recently, the problem of practical means of communication with intelligent beings existing elsewhere in the universe has attracted renewed attention, beginning in 1959 with Project Ozma and with an analysis of possible techniques published in *Nature* by G. Cocconi and P. Morrison of Cornell University. These ideas have a long prehistory, and the essential novelty of the new proposals is the realization that interstellar distances are involved and that radio is the only feasible medium of communication.

In the last century, the problem seemed simpler, when there was hope that only interplanetary distances had to be bridged, with the aid of light. It is said that C. F. Gauss envisioned vast geometrical symbols, for example, crops planted in regular patterns, that could be seen telescopically from other planets. Their inhabitants, thereby recognizing intelligent life on Earth, might be expected to respond in similar fashion. In Jules Verne's novel of a trip to the moon a related idea is mentioned. It is easy to smile at these naive suggestions, but the current proposals may be equally unrealistic in supposing that extraterrestrial "men" have faithfully duplicated our own technology.

Even the idea of space communication by radio is not quite new, as readers of H. G. Wells' *The First Men in the Moon* know. This novel appeared originally as a magazine serial in 1901. The year before, a great deal of publicity resulted from Nikola Tesla's ill-founded announcement that he had received radio signals presumably originating from the planet Mars. The newspapers magnified the story by linking it with Percival Lowell's press release a few days earlier that he had observed a bright "projection" at the edge of Mars.

Enthusiastic editors failed to realize that the Arizona astronomer was referring to a Martian cloud, and assumed some artificial attempt at signaling by supposed inhabitants of the red planet. Also in 1900, the Paris Academy of Sciences accepted a bequest of 100,000 francs, to be awarded as a prize for the first person to communicate with another planet. The stir occasioned by this combination of events lingered long in the popular mind, and in 1959 not a few people must have been reminded of it.

JOSEPH ASHBROOK

*Anleitung zur Geographischen Ortsbestimmung, Göttingen, 1852, page 250.

QUESTIONS... FROM THE S+T MAILBAG

Q. On the average, how many solar eclipses occur per century?

A. According to T. von Oppolzer, 237.5. Of these, 83.8 are only partial, 77.3 annular, 65.9 total, and 10.5 are total as seen from some parts of the eclipse track and annular from other parts.

Q. How bright are the individual stars in the great Hercules globular cluster, M13?

A. Helen Sawyer Hogg states that the average photographic magnitude of the 25 brightest stars (but excluding the five most bright) is 13.75. To a visual observer, the cluster as a whole appears as bright as a 6th-magnitude star.

Q. What is the separation of Saturn's rings from the ball of the planet?

A. The distance from Saturn's surface to the near edge of the inner ring (ring C) is 7,000 miles, while the outer edge of ring A is 48,000 miles from the planet.

Q. I observed an occultation of Gamma Librae by the moon on May 29, 1961, from Pennsylvania, but why is there no prediction of it in the Occultation Supplement of Sky and Telescope?

A. This occultation occurred less than 48 hours before full moon, and the supplement does not list the events for 4th-magnitude stars when the moon is very nearly full. This is because precise times are hard to observe with the moon so bright.

Q. Where is the Coalsack?

A. The most famous dark nebula of this name is in the southern sky, very near the Southern Cross (see page 89). There is also a small "northern coalsack" which, by coincidence, is close to the Northern Cross.

Q. Why are the minima of Algol given in the Celestial Calendar each month?

A. Algol is one of the brightest variable stars, and among the easiest to observe. Anyone interested in astronomy will enjoy watching this star go through at least one minimum, and it is for this reason that the predictions are published regularly.

W. E. S.

Interstellar material associated with hot early-type stars abounds in this part of the Large Magellanic Cloud, which includes at top center the great Tarantula nebula (30 Doradus). The enlargement is from an ultraviolet exposure made by Bengt E. Westerlund with Uppsala Observatory's 20-inch Schmidt telescope, located on the grounds of Mount Stromlo Observatory, Australia.

The Interstellar Medium

BART J. BOK, *Mount Stromlo Observatory*

ON THE COSMIC SCALE, 10 million years is just an instant. It represents 1/20 of the time that it takes our sun and most of the stars near us to circle once around the center of our Milky Way, and it is no more than 1/500 of the probable age of our solar system. Yet the maximum ages that we assign to some of the apparently very youngest stars are of the order of one to 10 million years. Most of these are stars with masses of 10 to 100 times the sun's, and they evolve quite rapidly.

We are thus forced to consider the possibility that cosmically very young stars are still being formed today from the matter in interstellar space, that is, from interstellar gas and cosmic dust. In many of the nearby parts of the Milky Way we observe an abundance of interstellar material, and these regions are also relatively rich in young and superluminous *O* and *B* stars. These extensive complexes of gaseous nebulosity appear to possess all the attributes required for star formation.

The most conspicuous manifestations of interstellar gas are the bright and beautiful emission nebulae, large and tenuous clouds of luminous gas. Among the best examples are the Orion nebula, the Eta Carinae nebulosity, and the 30 Doradus nebula in the Large Magellanic Cloud. What do we know about the emission nebulae, their compositions, their average densities, fluctuations of density; and by what processes are they made to shine?

According to the best available estimates, hydrogen atoms supply about 65 per cent of the total mass of such a nebula, with helium accounting for most of the remainder. Oxygen and calcium are probably next on the list, but their abundance is less than 1/1,000 compared to hydrogen and helium, and the abundances of other elements, sodium, potassium, and titanium, are smaller again by an order of magnitude.

Hydrogen is obviously the key element of interstellar space. Within the large emission nebulae, there are on the average about 50 to 100 hydrogen atoms per cubic centimeter, actually a better vacuum than we can obtain in the physical laboratory. Of vast size, the emission nebulae have diameters often as much as 100 light-years. The total masses of some nebulae and nebulous complexes may be as high as 25,000 to 50,000 suns, and we are thus assured that they contain plenty of gaseous matter for possible condensation into new stars.

Unlike stars, the emission nebulae are not self-luminous. They shine because of hot, blue-white *O* and *B* stars within their boundaries. With surface temperatures of 20,000° Kelvin and higher, these stars emit plentiful ultraviolet radiation, which ionizes the available neutral hydrogen atoms. Not infrequently, the resulting free electrons and protons recombine, the captures often being made in the higher energy levels of hydrogen atoms. The excited states last only a very short time, and as each electron cascades down to the lowest or Lyman level, lines of the familiar series — Paschen, Balmer, and Lyman — are produced in emission, thus making the nebula accessible to observation from the earth.

Best known of the many techniques for the study of emission nebulae is the straightforward optical analysis of their Balmer spectra and the associated background continuum. Additional information is obtained from the lines of other elements in various stages of ionization, notably helium, oxygen, nitrogen, and carbon. We also measure a nebula's total brightness and the distribution of surface brightness over its face. This photometry is best done with the aid of interference filters, which isolate the radiation of a single spectral line or of a small group of neighboring lines.

Radio techniques contribute much useful information. As a by-product of the recombination process between electrons and protons, a gaseous nebula emits strong radio radiation, especially in the wave length range from one to 20 centi-

meters. With some difficulty we may detect this sort of radiation all the way to the meter range. At the longest radio waves that are received from outer space, however, the emission nebulae are in effect absorbers, appearing as dark spots against a sky illuminated by radiation from more remote parts of the Milky Way and from the universe of galaxies.

At the other end of the spectrum, in the far ultraviolet, rockets afford means of observing from above the absorbing layers of the earth's atmosphere. At the Lyman-alpha line (1216 angstroms), the whole sky appears to be bright, but between 1225 and 1350 angstroms the familiar emission nebulae begin to show and some unexpected new regions of emission are detected.

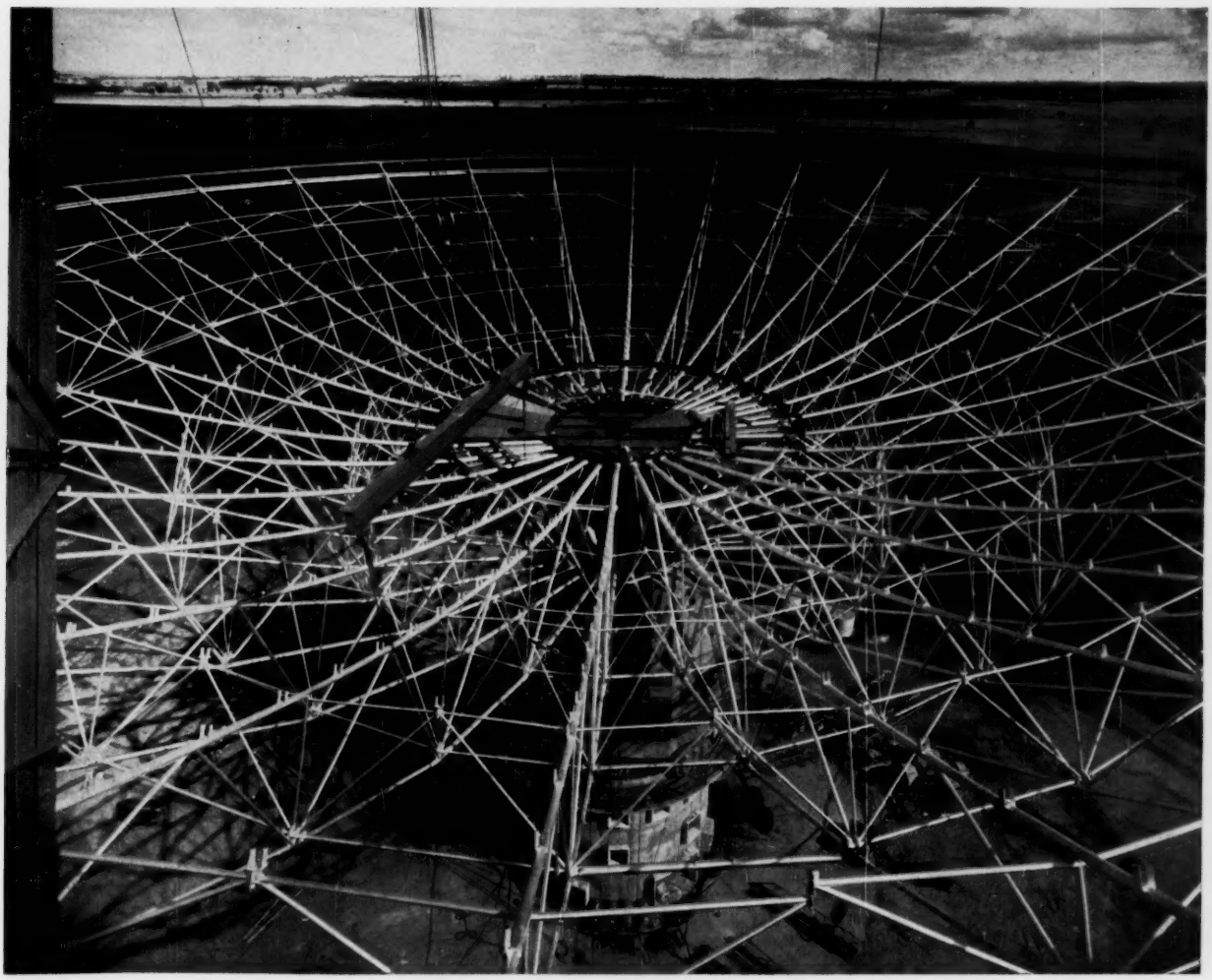
Perhaps the best physical model for a large emission nebula has the mass mostly concentrated in fairly dense small clouds, all of them together occupying only three or four per cent of the nebula's total volume. This model is based wholly on theoretical interpretation of spectral distribution and surface brightness of some large nebulae. Although it requires further observation and analysis, this model is very suggestive of incipient star formation.

Emission nebulae represent concentrations in the interstellar gas, but they are by no means the whole story. In the sun's vicinity, there is much gas outside the nebulae proper, concentrated largely within a layer 1,000 light-years thick near the central plane of the Milky Way. The average gas density is of the order of one hydrogen atom per cubic centimeter, but it is 10 times as great in the spiral arms as between them.

The optical technique of detecting interstellar gas by the absorption lines it produces in stellar spectra was described in the May, 1961, SKY AND TELESCOPE by Otto Struve (page 269), so we need not repeat it here. Filter techniques may also be used, as shown by some of the accompanying photographs, but the most recent and striking method of observation is by radio.

In the radio spectrum, emission and absorption at a wave length of 21 centimeters can be produced by the neutral hydrogen atoms of the interstellar gas. The process depends on the hyperfine structure of the atom's lowest (Lyman) energy level. The single electron can have a magnetic spin that is in the same or opposite direction to the spin of the atom's nucleus, the difference of energy in the two situations corresponding to that of the 21-cm. line. A single hydrogen atom probably changes from one of these energy states to the other only once every 300 years, but the number of atoms along almost any line of sight is so great that we receive on earth sufficient radiation at 21 centimeters to detect it with large radio telescopes. The total intensity tells roughly how much hydrogen there is in a particular direction.

If all the hydrogen in the galaxy were at rest relative to the sun, there would be only one very narrow line in the radio spectrum at 21 centimeters. But the Milky Way system rotates, and hydrogen clouds



This is an aerial view of the paraboloidal dish of the 210-foot radio telescope at Parkes, Australia, from high up on the derrick at the left in the front-cover picture. Although it has an altazimuth mounting, the giant reflector will be driven in equatorial co-ordinates by a conversion device and error detector, as described in this magazine's October, 1959, issue, page 666. Photograph from Commonwealth Scientific and Industrial Research Organization.

Interstellar gas and dust are inextricably intertwined in Messier 8, a prominent nebula in Sagittarius. Some small, roughly circular dark patches are examples of globules. This is a 30-minute exposure with the 82-inch reflector of McDonald Observatory on Mount Locke in Texas.

at various distances from the galactic center move with different speeds around it. In addition, the clouds have motions of their own, and all these movements combined give us a Doppler pattern of considerable complexity along most lines of sight.

From the appearance of the intensity profile (intensity versus precise wave length) of the 21-cm. line observed for any particular direction, we may deduce how much neutral hydrogen there is present at specific radial velocities of approach and recession. And if we possess — as we do — a rotational model of the galaxy, we can assign to each observed radial velocity a distance from the earth. Similar analyses for many different directions permit building up a picture of the distribution of neutral hydrogen atoms in most parts of the Milky Way system, reaching even to distances far greater than that of the center.

Radio studies have one great advantage over optical observations, for in radio we are not bothered perceptibly by the obscuring effects of cosmic dust. Its presence close to the central plane of the galaxy limits optical studies for the Milky Way band to distances generally less than 10,000 light-years. Radio waves penetrate cosmic dust without being affected by it, permitting us to reach to the galactic center and beyond.

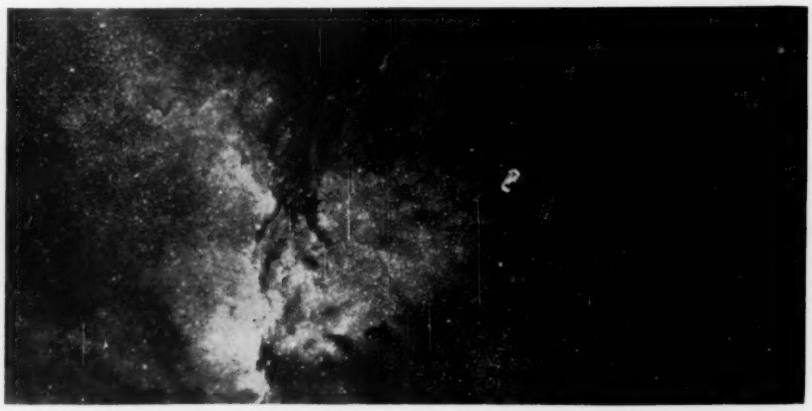
The 21-cm. observations delineate more clearly than any other type of observation the spiral structure of the galaxy, at the same time providing an increasingly detailed picture of the cloud structure of the interstellar medium. We can obtain data on average densities, temperatures, masses, and motions of the neutral atomic hydrogen clouds. With several large precision radio telescopes under construction, and with improved techniques for recording faint radiations, it should not be many years before the fine structure of interstellar gas clouds will be understood.

These radio observations and other studies enable us to estimate that the total mass of our galaxy, stars, gas, and dust combined, is close to 100 billion solar masses. Only two per cent is interstellar gas, mostly neutral hydrogen, with ionized hydrogen only 1/20 of the gas total. In the sun's neighborhood, where spiral structure prevails, the interstellar gas may account for 10 or 15 per cent of the total mass. This estimate is uncertain principally because we do not know the possible contribution to the total by molecular hydrogen. Neither optical nor radio techniques provide as yet a way for its detection, and it may be one of the most common gases of interstellar space.

Cosmic dust plays a spectacular but relatively minor role when compared with the interstellar gas. Milky Way photographs, such as those by E. E. Barnard described in this magazine in July (page 14), give ample evidence of dark lanes of obscuring matter observed against the Milky Way star clouds and projected on the large emission nebulae. With the naked eye we can easily recognize the Southern Coalsack, directly east of Crux. With a diameter of about 10 light-years, its total dust content equals 30 to 50 solar masses.

If the dust is in the vicinity of cool, relatively bright stars, or a group of stars, the dark nebula is made to shine by reflected light. The Pleiades cluster has such reflection nebulosities associated with it. From the nature of the reflected light we can learn much about the dimensions and electrical properties of the tiny dust particles. Also, since interstellar dust polarizes and reddens the light of stars beyond it, we have been able to deduce that the most common type of dust particle is probably slightly elongated, with an average diameter of 1/100,000 inch. In all likelihood it is composed of molecular combinations of familiar elements, such as carbon, nitrogen, oxygen, and the ever-present hydrogen.

There are many very small dark nebulae, some of them highly concentrated features named *globules*. Their dimensions are as small as 1/100 light-year, which is comparable to an oversized solar system. While globule masses are quite



A complicated region of the southern Milky Way, including at the left a gaseous nebula mixed with lanes of obscuring dust and at the right a bright hook-shaped gas cloud. Photograph by Bengt E. Westerlund with the 20-inch Schmidt telescope of Uppsala Observatory.

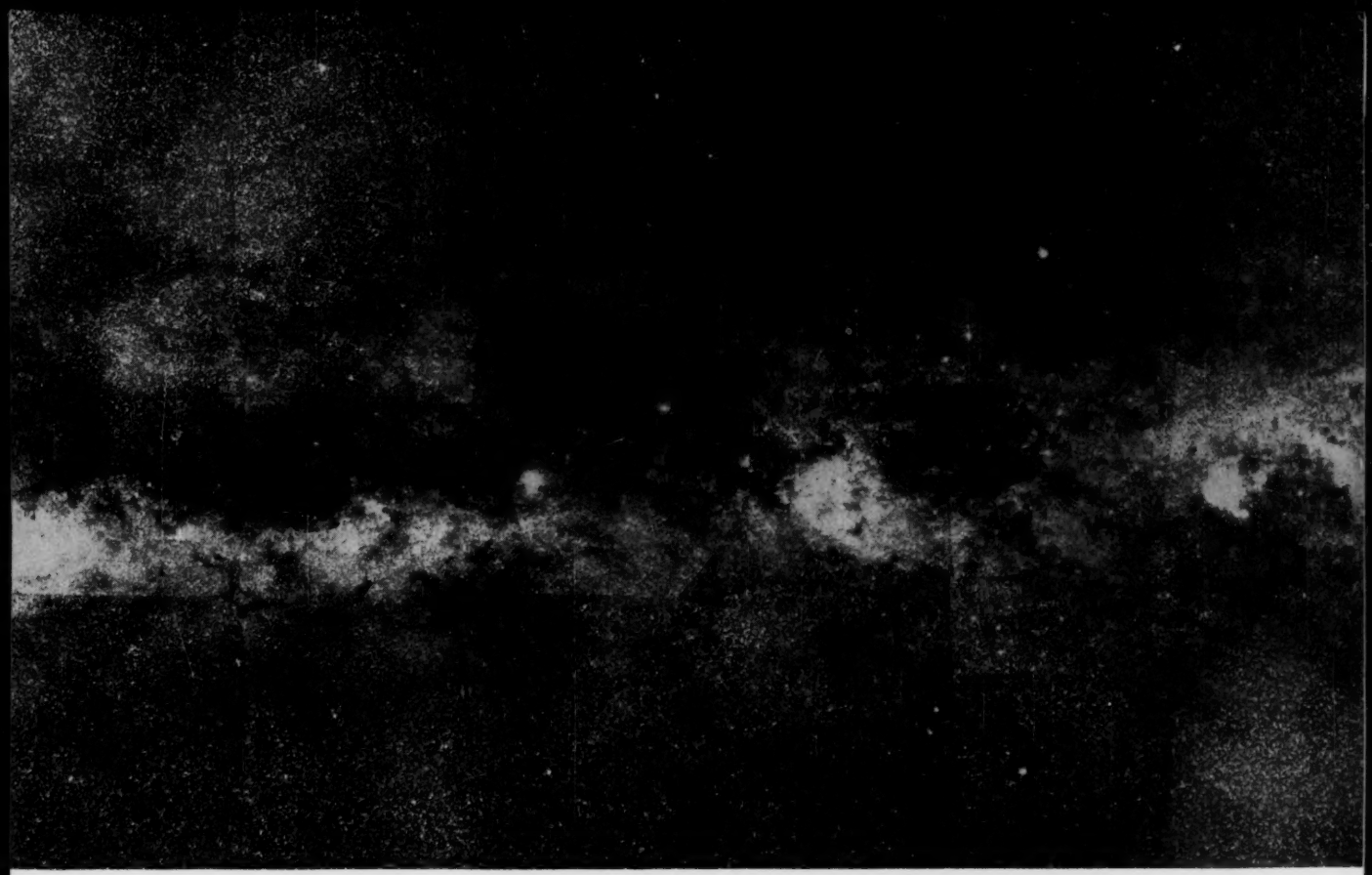


Plate 3 of an atlas of H-II regions in the southern Milky Way, from photographs taken with the 8-inch Schmidt camera at Mount Stromlo Observatory by A. W. Rodgers and J. Whiteoak. The mosaic was assembled by Helen Bailey and V. O. Hunt. From left to right, it covers galactic longitude 300° to about 255°, overlapping the section on the next page. To the right of center is the Coalsack, a large dark nebula next to the Southern Cross. The star Beta Centauri is almost centered, with Alpha Centauri overexposed to the left and below it. Constellations Ara, Norma, and Lupus lie along the left edge, where there are relatively few hydrogen emission nebulosities. In the richer region at the right edge is Carina. Triangulum Australe, Circinus, and Musca lie along the bottom central part of the picture. This section of the Milky Way is its southernmost. Reproduced courtesy Australian National University.

uncertain, they are not much greater than the sun's. No data is available concerning the association of hydrogen gas with dust in globules. But several emission nebulae exhibit small globules in considerable numbers at their outer edges, and cosmic dust, as well as bright nebulosity, is abundant in many associations and clusters of *O* and *B* stars.

It seems not unlikely that these tiny dark clouds are a mixture of gas and dust now in the process of contraction — the most likely nuclei for the formation of new stars. They will, first of all, tend to contract under their own gravitational action, and a collapse, once started, will be a self-accelerating process. It will be aided by radiation pressure exerted upon a globule from the outside, and probably even more by the high gas pressure exerted by ionized gas at the boundary region between ionized and neutral hydrogen. Finally, magnetic forces may help squeeze globules together.

We do not suppose that all globules collapse in a neat and predictable fashion. More likely many of the observed objects are of a highly temporary nature, to be blown to bits by what we might loosely call the cosmic winds. But an occasional globule should encounter conditions that encourage collapse, which once started will almost surely lead eventually to a thin and very extended star, set on the first steps of its evolutionary path.

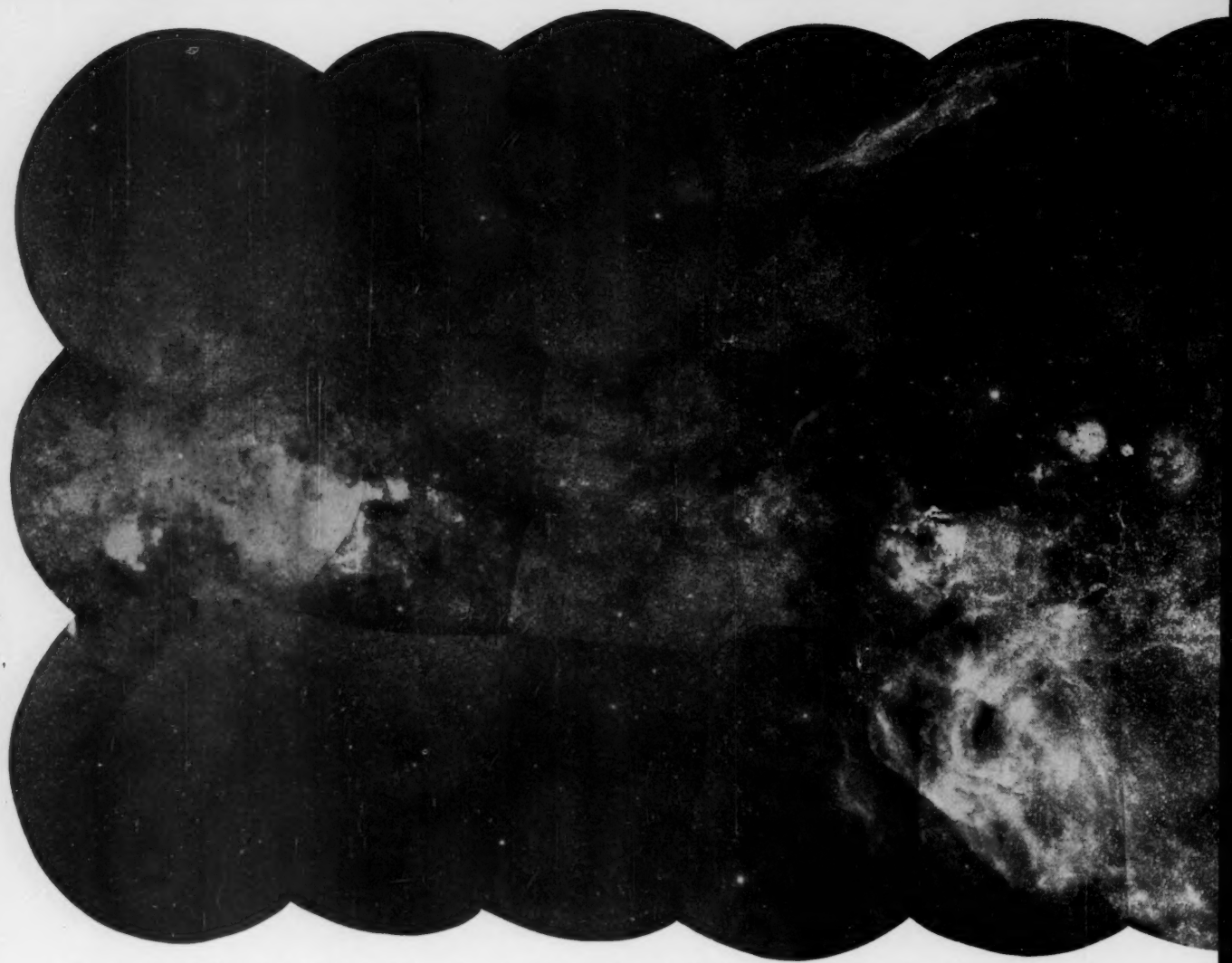
In the vicinities of some of the best-known dark nebulae, very faint dwarf variable stars, named after their prototype T Tauri, are generally recognized as the first observed stages of stars in evolution. In two cases we may even have seen a T Tauri variable come into sight before our eyes within a few years (Sky and Telescope, December, 1955, page 59).

For reasons not yet understood, the interstellar gases in the Milky Way and other spiral galaxies seem to follow a spiral pattern. Associated with their arms are large-scale magnetic fields whose lines of force follow the spiral pattern reasonably closely, and this may serve to concentrate the interstellar gas. But we lack a sound theoretical approach to the problem.

Spiral arms of interstellar gas would, however, seem to be rather short-lived features of a galaxy. The inner parts of a spiral arm whirl around the system's center faster than the outer parts. A gradual winding up of the spiral pattern seems almost inevitable, at least in two or three galactic revolutions, say 500 million years, which is still only 1/10 of the age of the solar system, 1/20 or less of the age of our universe.

A related problem is the exhaustion of interstellar gas because of the continuing process of condensation into stars, which should also limit a spiral arm's lifetime to two or three galactic revolutions. In galaxies outside our own, the best-developed spiral arms rarely exhibit more than one and a half convolutions — the inner parts cannot have made many more circuits around the centers of these galaxies than have the outer parts.

Although the question of replenishment of spiral arms is unanswered, we may speculate a bit. Radio astronomers in the Netherlands have found considerable amounts of interstellar hydrogen, most of it neutral, some of it ionized, in the central parts of our galaxy. There is even a suggestion of a major spiral arm only one third as far from the galactic center as the sun is. This "10,000 light-year arm" has the amazing property of moving outward with a speed of 30 miles per second. If this rate were maintained,



A composite of Plates 2 and 1 of the Mount Stromlo atlas, overlapping (at the left) part of Plate 3 on the preceding page. The great nebulous complex at bottom center is the Gum nebula, named for its discoverer, the late Colin S. Gum.

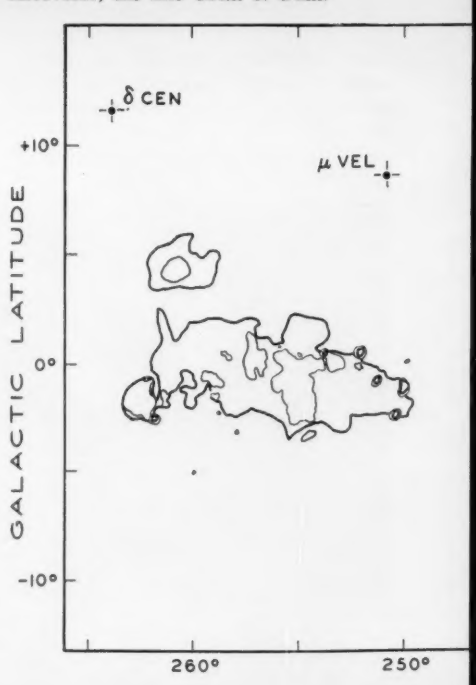
the whole spiral feature would be carried out to the sun's present position in a little over 100 million years. We may consider the hypothesis that the expanding arms near the center will eventually move outward to take the place of the present spiral arms when the supply of interstellar gas in the latter becomes exhausted.

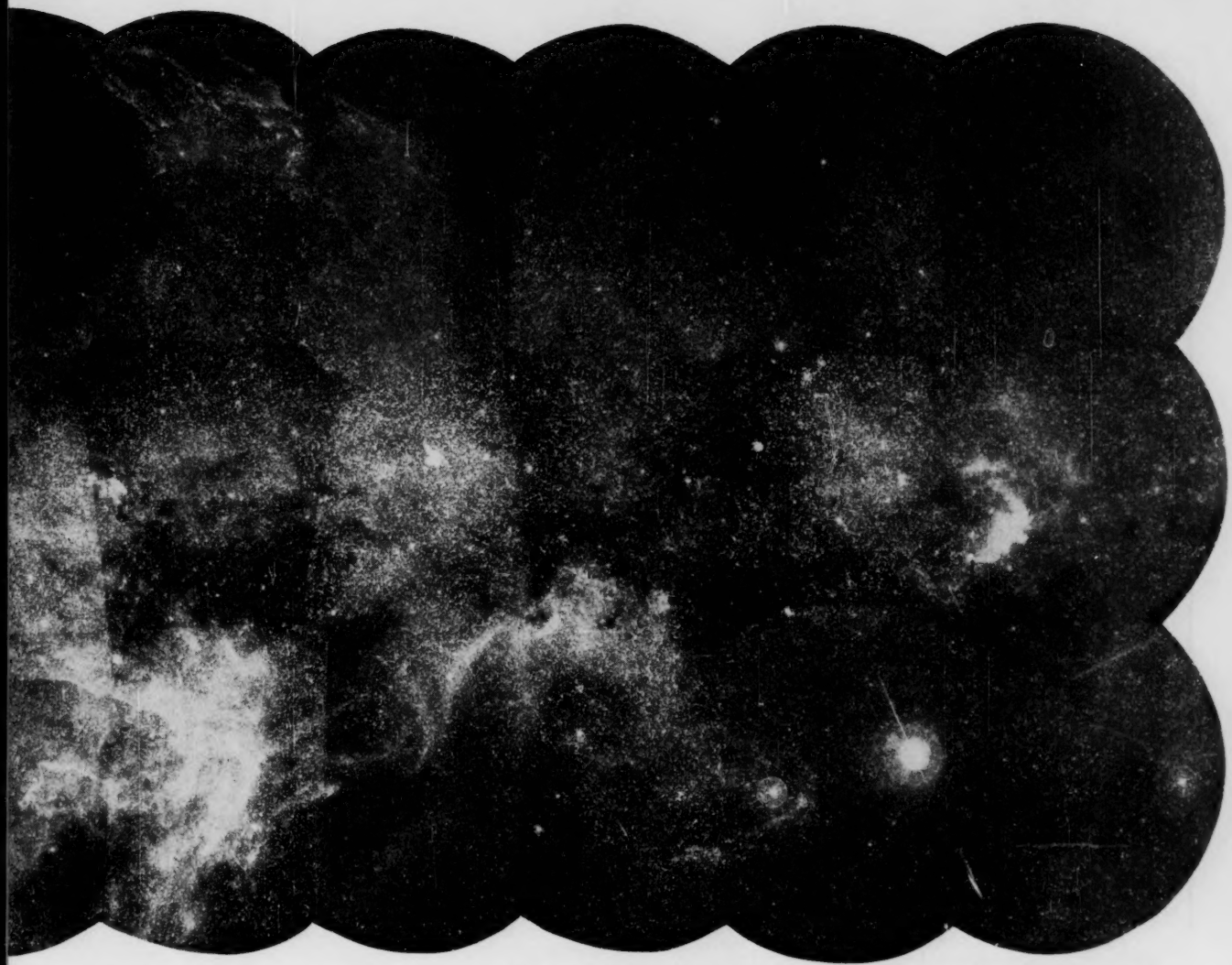
It is notable that star formation does not seem to take place, at least not on a large scale, in the central regions of the Milky Way and other galaxies; it is an active process only in their outer parts. The Sydney radio astronomer Frank J. Kerr has recently suggested that interstellar hydrogen at the sun's distance from the center moves outward at five miles a second. This indicates that the gas rings expelled from the central regions at 30 miles per second slow down considerably as they advance.

From where, then, would the central regions obtain their fresh supplies of gas to shoot out these expanding "smoke rings"? One suggestion does not seem very attractive: that Population II stars suffer either very violent or very mild explosions and expel the gases into space. A preferable idea is that gas is supplied by the thin outer gaseous halo indicated by radio observations to surround the Milky Way system.

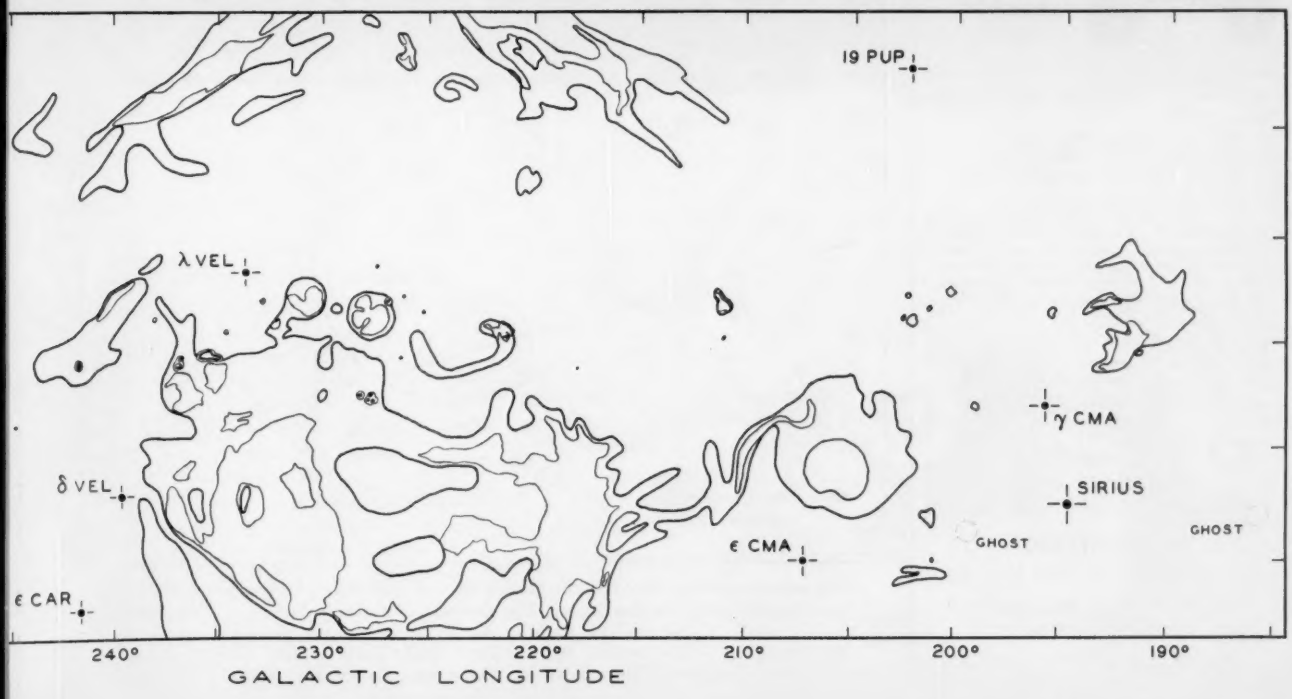
The best explanation of the general galactic radio radiation in the meter range is that it comes from a low-density ellipsoidal cloud enveloping the Milky Way. With a temperature of perhaps a million degrees Kelvin, the halo's hydrogen is completely ionized, the radio radiation being produced as free electrons spiral around the lines of force that probably lead into the nucleus of the galaxy. Perhaps the expanding gaseous rings in the nuclear regions of ours and other galaxies are produced as a by-product of this large-scale process. These ideas, however, must be considered quite conjectural, serving principally as working mechanisms.

One thing is quite clear. The solution of many problems in star birth and evolution lies in our obtaining as complete information as possible about the distribution, state of motion, and physical conditions in the interstellar medium.





As the key chart shows, these 33 exposures with the 8-inch Schmidt camera cover an 80-degree section of the Milky Way, from Sirius on the right to the Carina-Centaurus nebulosities on the left. Mount Stromlo Observatory photograph.



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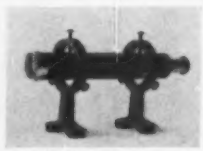

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OBSERVER'S PAGE

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Lunar Eclipse in August

FRIDAY EVENING, August 25th, will present an opportunity for completely observing a nearly total eclipse of the moon from everywhere in the Americas except the west coasts of the United States and Canada. The main event will be the umbral eclipse from 7:35 p.m. Central standard time to 10:41, although a slight penumbral darkening of the moon will be visible shortly before and after.

The following table, adapted from the *American Ephemeris,* gives Central standard times for the main stages.

Moon enters penumbra	6:36 p.m.
Moon enters umbra	7:35
Middle of eclipse	9:08
Moon leaves umbra	10:41
Moon leaves penumbra	11:40

To convert to EST, add one hour; to obtain MST, subtract one hour; for PST, subtract two hours. If you are using daylight time, increase the result by an hour.

The convenient time of evening on a weekend in comfortable summer weather makes this eclipse particularly favorable for public observing parties or for amateur group projects. The spectacle may be watched as a beautiful natural phenomenon, or a planned program of observations may be undertaken. From either point of view, the event is one of the astronomical highlights of 1961.

In the Los Angeles area, where the Western Amateur Astronomers will be meeting, the eclipsed moon will rise about 6:10 PST, some 20 minutes before sunset. As a result, the moon will be unfavorably placed, low in a bright sky, until mid-eclipse. Twilight ends about three quarters of an hour before the close of the umbral phase.

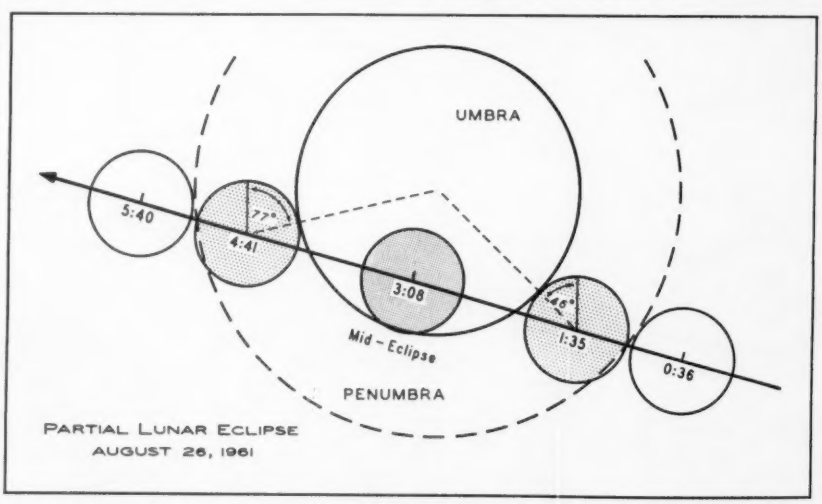
Farther east, conditions are more favorable. For example, at Tulsa, Oklahoma, the moon rises at 6:43 p.m. CST, nearly an hour before it begins to enter the earth's umbral shadow.

As the diagram shows, the moon very nearly becomes totally eclipsed, only 0.008 of its diameter remaining outside the dark inner shadow. Because of this tiny segment outside the umbra, there may be a narrow lighter crescent that will appear to swing from southwest through south to southeast near the time of mid-eclipse. This phenomenon will be an attractive subject for photographic observers.

At greatest eclipse, the northern edge of the moon will be inside the dark central portion of the earth's shadow, while the southern edge, as mentioned, should be just outside the umbra. Hence the gradation of brightness and color across the moon from north to south deserves special attention. The colors of the shadowed moon differ markedly from one eclipse to another, and careful descriptions are valuable.

The larger the telescope used, the less marked are the eclipse colors. For their study, small portable telescopes, binoculars, and the naked eye are best. It is important that every recorded color observation include a note of the time and of the instrument used.

How long before the predicted beginning of umbral eclipse can the faint penumbral darkening of the moon first be seen? On some previous occasions the interval has been recorded as anywhere from about 15 to 30 minutes. Can this shading be seen sooner with low-power finders or binoculars than with the un-



The moon's passage through the earth's shadow will take place at the Universal (Greenwich) times shown here. The outer, penumbral shadow is very weak, except where it borders the umbra. As the moon moves eastward across the southern part of the umbra, the northern lunar limb will be darkest at mid-eclipse. Chart based on "American Ephemeris" data.

aided eye? A similar study can be made of the visibility of the penumbral darkening after the end of umbral eclipse.

The size of the earth's shadow appears slightly larger than predicted from geometrical considerations, and this enlargement shows some variation at different eclipses. Two kinds of amateur observations are very useful in investigating this problem. One consists in noting as accurately as possible the times of beginning or ending of eclipse; the other is timing when particular craters enter or leave the umbra.

The times should be recorded to the nearest 0.1 minute, and the clock or watch corrected to at least this accuracy. For larger craters, it is possible to note three times: when the shadow edge first touches the crater, when it bisects it, and when the shadow edge reaches the opposite wall. In the case of smaller craters, the time recorded is when the shadow reaches the middle of the crater. Telescopes of between 2- and 6-inch aperture, with powers from 25 to 50, are well suited for such observations.

It is not easy to identify lunar features during an eclipse, hence observers unfamiliar with them may profitably spend a practice session on a previous night, comparing the moon with a chart. If there is doubt as to the identity of any crater timed, it is best to discard the observation.

Experienced observers are invited to make crater timings through color filters to provide data for ascertaining whether the shadow size depends appreciably upon color. A suggested procedure is to time a considerable number of craters, the first with a blue filter, the second with a red one, the third with no filter, repeating this sequence as often as possible.

The writer will undertake an analysis of any timing observations reported by readers. All eclipse reports and photographs should be mailed without delay to SKY AND TELESCOPE, 49 Bay State Rd., Cambridge 38, Mass. To be useful, reports must include the sizes, types, and magnifications of instruments used, together with information on sky conditions.

R. N. W.

MARS-URANUS CONJUNCTION

Two readers report seeing Mars just after it passed 0.6 degree north of Uranus on June 15th. George Zerambo of Bentleyville, Pennsylvania, watched the two planets in the evening sky for about an hour in his 3-inch reflector. It was his first observation of such an event.

In New Britain, Connecticut, Philip L. Dombrowski used 7 x 35 binoculars and a 4-inch reflector with powers from 40 to 225. Through the binoculars Uranus appeared as a faint star, while at low magnification the telescope showed it as a green point of light, greatly outshone by Mars. At highest power, the disk of the 6th-magnitude planet was visible.

OCCULTATION OF PORRIMA BY THE MOON

FROM California, where poor skies hindered operations, and the Midwest, favored by much better weather, amateurs reported observing the occultation on June 21-22 of the bright double star Gamma Virginis, magnitudes 3.6 and 3.7.

Robert L. Sandy reports careful timings by members of the Kansas City Astronomy Club. When each component of Porrima disappeared, a stop watch was started, then stopped at the WWV signal marking the beginning of the next minute. Differencing gave the time of the star's disappearance behind the dark limb of the moon.

Two of this group, D. D. Clarke and Brook Sandford, observed at the Kansas City Moonwatch station, whose co-ordinates are known with great accuracy — longitude 94° 34′ 41″.5 west, latitude 39° 01′ 59″.2 north, elevation 951 feet. Using a 6-inch reflector at 200x and a 3-inch refractor at 45x, respectively, they timed the disappearance of the first star as 4:40:51.2 Universal time, the second as 4:40:56.9. The two stars emerged from

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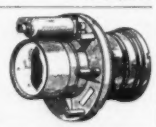

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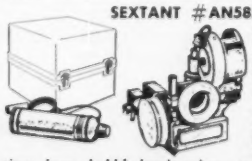

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the moon's bright edge at 5:15:08.6 and 5:15:15.2.

Mr. Sandy's own observations were made with a 6-inch reflector, 214x, at his home in Independence, Missouri (94° 26′ 32″ west, 39° 03′ 15″ north, elevation 1,025 feet). He found that the two components of Gamma Virginis disappeared at 4:41:04.5 and 4:41:10.4.

In Terre Haute, Indiana, Rev. George E. Mitchell timed the event with a 6-inch reflector and tape recorder; Wayne Herrington watched the occultation from Long Beach, Mississippi. At Battle Creek, Michigan, there was no occultation, reports A. J. Morehouse. Instead, the double seemed to pass the moon's northern edge by about half a minute of arc, closest approach being at 4:56:47, as estimated using his 5-inch f/5 refractor at 16x.

Clouds and fog closed in to prevent emersion observations by Jason White in Whittier, Neil Zakar in La Mesa, and Brenton Bennet in Los Angeles, California. These three amateurs, however, were able to time the immersion of Porrima, using 8-, 6½-, and 6-inch reflectors, respectively. Carroll L. Evans, Jr., was more fortunate, and could observe both disappearance and reappearance from China Lake, California.

METEOR SHOWER FROM BOOTES

On the evening of May 15, 1961, I saw a brilliant white meteor, of magnitude −1, that traveled 25 degrees northward from a point west of Arcturus. Appearing at 8:17 Central standard time, it was quickly followed by six other meteors of magnitudes 2, 3, and 4, from the same radiant. During the next 15 minutes I observed 12 more members of this shower, and one sporadic meteor. I plotted their paths on a star chart, and may have missed some additional meteors while writing. The plot gives the right ascension and declination of the radiant as $13^h\ 40^m$, +21°.

I would like to hear from other amateurs who witnessed this short-lived burst of meteoric activity. The available literature does not mention a shower on this date from such a radiant.

JOHN V. FAY, III
7 Woodham St.
Fort Walton Beach, Fla.

OBSERVATIONS OF SATURN AND THE MOON

Several readers have commented on the observations on page 337 of the June issue, made by George Caragiorgis, Athens, Greece. There he reported that on June 13, 1957, he had seen the outer (A) ring of Saturn as definitely blue; also, on September 8, 1957, he had seen radial dark bands inside the lunar crater Copernicus.

Craig L. Johnson, Boulder, Colorado, states that he viewed Saturn on three

nights in June of that year, without noticing any special color of the outer ring. Rodger W. Gordon points out that he has frequently seen a false bluish tinge to the A ring, the result of secondary chromatic aberration in his 2.4-inch refractor. He suggests that the color seen by Mr. Caragiorgis may have been of similar origin, as the Greek observer also used a refractor.

Leif J. Robinson, Torrance, California, reports having observed the dark bands in Copernicus. He has made an extensive study of banded craters, finding that in nearly every case these craters appear very bright near full moon, a property shown by Copernicus.

OBSERVATIONS OF RZ CASSIOPEIAE WANTED

RZ Cassiopeiae is an eclipsing variable star that fades from its normal magnitude, 6.4, to 7.8 at intervals of 1.195 days. A chart in which the magnitudes of comparison stars are marked was published on page 310 of SKY AND TELESCOPE for November, 1960, together with an explanation of how to make visual observations from which times of minima can be derived. Additional information about this star was given on page 218 of the April, 1961, issue.

During September, primary minima are predicted for the following dates and Universal times, expressed in hours and tenths:

September 1, $21^h.4$; 3, 2.1; 4, 6.8; 5, 11.4; 6, 16.4; 7, 20.9; 9, 1.5; 10, 6.2; 11, 10.9; 12, 15.6; 13, 20.3; 15, 1.0; 16, 5.7; 17, 10.3; 18, 15.0; 19, 19.7; 21, 0.4; 22, 5.1; 23, 9.8; 24, 14.5; 25, 19.2; 26, 23.8; 28, 4.5; 29, 9.2; 30, 13.9.

October 1, $18^h.6$; 2, 23.3; 3, 4.0; 5, 8.6.

Readers who make observations of RZ Cassiopeiae are invited to send transcripts of their estimates to SKY AND TELESCOPE for evaluation of the times of minimum.

SUNSPOT NUMBERS

The following American sunspot numbers for May have been derived by Dr. Sarah J. Hill, Whitin Observatory, Wellesley College, from AAVSO Solar Division observations.

May 1, 86; **2,** 67; **3,** 70; **4,** 51; **5,** 34; **6,** 23; **7,** 29; **8,** 26; **9,** 36; **10,** 31; **11,** 38; **12,** 45; **13,** 33; **14,** 30; **15,** 28; **16,** 23; **17,** 24; **18,** 39; **19,** 47; **20,** 63; **21,** 48; **22,** 67; **23,** 60; **24,** 52; **25,** 52; **26,** 36; **27,** 28; **28,** 23; **29,** 28; **30,** 28; **31,** 23. Mean for May, 40.9.

Below are provisional mean relative sunspot numbers for June by Dr. M. Waldmeier, director of Zurich Observatory, from observations there and at its stations in Locarno and Arosa.

June 1, 30; **2,** 42; **3,** 48; **4,** 62; **5,** 55; **6,** 49; **7,** 40; **8,** 45; **9,** 58; **10,** 77; **11,** 82; **12,** 72; **13,** 75; **14,** 80; **15,** 123; **16,** 128; **17,** 128; **18,** 128; **19,** 112; **20,** 116; **21,** 128; **22,** 123; **23,** 96; **24,** 96; **25,** 72; **26,** 56; **27,** 51; **28,** 38; **29,** 59; **30,** 63. Mean for June, 77.7.

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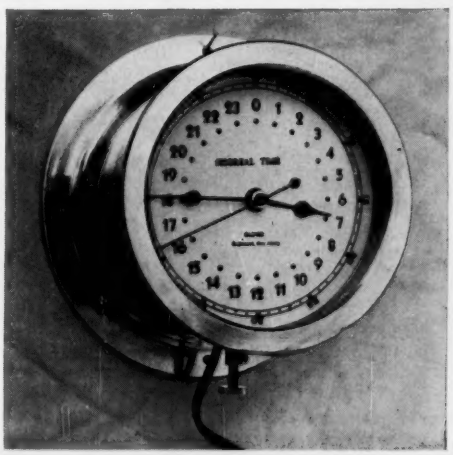

The minute circle is 4 inches in diameter. The case is machined cast aluminum, polished and buffed; and the bronze bezel is polished and lacquered. Hour and minute hands are set with the knob at the bottom of the case. Computed accuracy is within 3.75 seconds a year slow (assuming the frequency constant). Please specify your current: 60-cycle, 110-volt; 50-cycle, 110-volt; or 60-cycle, 220-volt.

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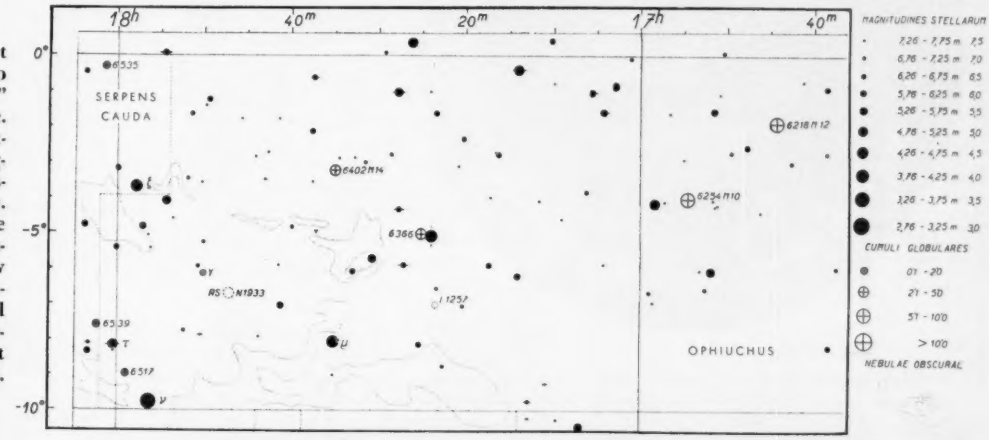
DEEP-SKY WONDERS

AMATEURS interested in globular clusters will find them conveniently plotted in the Skalnate Pleso *Atlas of the Heavens*. On the whole, the atlas is easy to use, but it is well to note that different classes of objects are not treated in the same way. Stars are recorded only to slightly below naked-eye limits, galaxies to magnitude 13.5. Some open clusters may be missing, even though within the reach of a 10-inch instrument. Almost all planetary nebulae and globulars are included, regardless of faintness, except for some of the nonexistent objects erroneously listed in the *New General Catalogue* (such as NGC 4153).



A reproduction of part of the Skalnate Pleso "Atlas of the Heavens," about 7/10 original scale. The key at right (in Latin) identifies stellar magnitudes, globular clusters, and dark nebulae. Objects not listed in the key are an open cluster (dotted circle, below center), a nova that appeared in 1933 (dashed circle at left), and a variable star (circled dot northeast of the nova).

Prominent these August evenings is the region shown in the chart from the Skalnate Pleso *Atlas*. This central part of Ophiuchus, lying between the two sections of Serpens, provides a test for the observing capabilities of amateurs with modest-sized telescopes.

Proceeding from west to east, the first cluster is NGC 6218 (M12), which is nine minutes of arc in diameter according to the Skalnate Pleso *Atlas Catalogue*, but which Helen S. Hogg calls 12′ in her list of globulars. It is of 7th magnitude, at right ascension $16^h\ 44^m.6$, declination $-1°\ 52'$ (1950 co-ordinates), in the relatively empty region east of Serpens Caput. A few degrees to the southeast is NGC 6254 (M10), at $16^h\ 54^m.5$, $-4°\ 02'$, its size 8′ (Skalnate Pleso) or 12′ (Hogg). Of magnitude 7, M10 was considered by William Herschel as similar in appearance to the globular M53 in Coma Berenices.

The visual diameters of globular clusters depend to some extent on the size of telescope and the observer's eyesight. Members of an observing group should compare their individual estimates of these objects' sizes, using a micrometer, an ocular grid or reticle, or by timing transits over a crosshair in the eyepiece. The results may well be quite different for telescopes of different sizes. Similarly, apparent magnitudes may differ in large and small instruments.

Considerably farther east lies NGC 6366, in the same field as the naked-eye star 47 Ophiuchi. This globular is about 6′ in diameter and quite faint, magnitude 12. It might be difficult for a small telescope, especially with the interfering glare of the bright star. Look for this globular at $17^h\ 25^m.1$, $-5°\ 02'$. Only a few field diameters away is the much easier cluster NGC 6402 (M14), at $17^h\ 35^m.0$, $-3°\ 13'$. Three to seven minutes in diameter, of magnitude 8 or 9, it is readily seen in an apogee Moonwatch telescope, which has an aperture of 4.7 inches.

At the eastern edge of the chart are three smaller, rather faint globulars. About halfway between Nu and Tau Ophiuchi, at $17^h\ 59^m.1$, $-8°\ 57'$, is 12th-magnitude NGC 6517, only 1′ in diameter. I have seen it in Kansas after some effort with a 10-inch instrument, though perhaps the night was not good. North of it and in Serpens is NGC 6539, at $18^h\ 02^m.1$, $-7°\ 35'$, equally faint but 2′ or 3′ in diameter. Farther north is NGC 6535, 1′.3 across and also of magnitude 12. Its position is $18^h\ 01^m.3$, $-0°\ 18'$.

Amateurs who have successfully worked down from the brighter globulars to such faint ones can feel well satisfied with their observing prowess.

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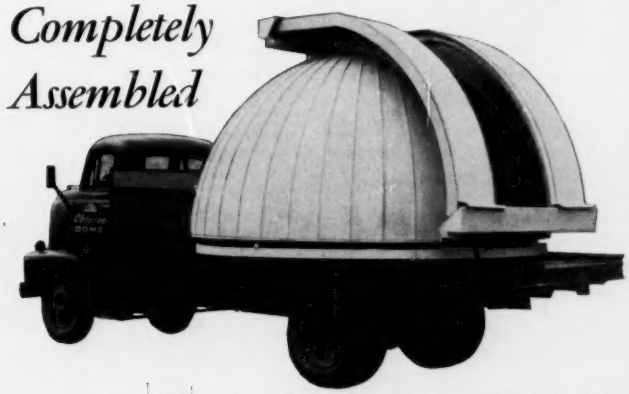

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Particularly suited for observing with small telescopes is **Norton's Star Atlas,** a familiar and famous reference handbook. Covering the entire heavens, it shows over 9,000 stars to magnitude 6.35, nebulae, and clusters. There are descriptive lists of 500 objects, and sun, moon, and planet data. *108 pages.* **$5.25.**

Forming a more detailed atlas are 16 charts developed by Antonin Becvar and his associates at the Skalnate Pleso Observatory in Czechoslovakia. 35,000 stars to magnitude 7.75, with double, multiple, and variable stars, novae, clusters, globulars, and planetaries, bright and dark nebulae, galaxies, the Milky Way and constellation boundaries, are printed in color in the **De Luxe Atlas of the Heavens,** the 16½" x 23" maps being bound in a heavy cloth cover. **$9.75.**

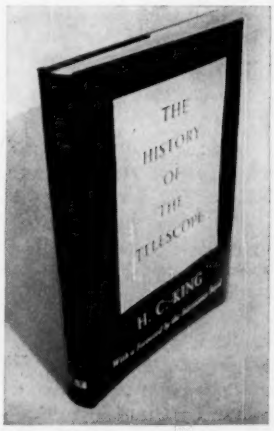
The inexpensive **Field Edition** of the Skalnate Pleso atlas is a most convenient star reference. 16 sheets of stiff paper, 18" x 12¼", are printed in white on a black background. The charts are unbound. **$4.00** *per set; two sets for* **$7.50.**

Antonin Becvar's **Atlas Coeli-II Katalog 1950.0** is the most complete check list of celestial objects ever offered the amateur. Given, with descriptive data, are the 6,362 stars brighter than magnitude 6.26, and extensive lists of clusters, nebulae, and galaxies. *367 pages,* **$8.75.** The catalogue and the *De Luxe Atlas of the Heavens* sell together for **$17.50.**

Lunar observing is more informative with **Elger's Map of the Moon,** a large canvas-mounted chart, approximately 18" in diameter, identifying all important lunar features. **$3.00.**

An Atlas of the Moon's Far Side, the most recent Sky publication (jointly with Interscience Publishers, Inc.), is the full account of the photographic reconnaissance of the moon by the Soviet Union's third space probe, Lunik III. Launched on October 4, 1959, the probe carried advanced scientific equipment that included photographic and television systems; it passed around the moon to view a portion of the lunar surface that is perpetually hidden from Earth. On command, Lunik III photographed the moon's far side for 40 minutes, and these images were later telecast to earth.

The results of this achievement were compiled for the U. S. S. R. Academy of Sciences by three leading Soviet astronomers, N. N. Barabashov, Kharkov University Observatory, A. A. Mikhailov, Pulkovo Observatory, and Yu. N. Lipsky, Sternberg Astronomical Institute. Now the complete Russian *Atlas of the Opposite Side of the Moon* has been translated into English by Richard B. Rodman of Harvard Observatory. This volume contains every fact, every illustration, in the Russian original. Included are all 20 full-page plates with their 30 halftone pictures of hitherto invisible lunar features. These pictures were obtained by an ingenious electronic filtration process, described in the text, from the best Lunik III original negatives. An important part of the book is the catalogue of 498 lunar formations. The definitive map is given in two forms — both as four full pages in the book, and as a separate 17" x 24" folding sheet. *200 pages (8⅜" x 11⅞"), 20 plates,* **$7.00.**



From numerous original sources, Henry C. King, now director of the London Planetarium, has compiled a full account of the development of the telescope from crude early types to the powerful giants of today. In **The History of the Telescope,** many instruments are illustrated by historic drawings and modern photographs. More than an account of the evolution of the telescope, this book gives much information about craftsmen and instrument makers, and about associated advances in astronomy. It provides a gold mine of ideas for amateur telescope makers. *456 pages, 196 illustrations,* **$7.50.**

Making Your Own Telescope, by Allyn J. Thompson, contains complete step-by-step directions for making and mounting a 6-inch reflector at low cost. In easy-to-understand chapters, the amateur learns how to grind, polish, and figure the mirror, and how to make an equatorial mount that will provide a sturdy, solid support for his optics. *211 pages, 104 illustrations,* **$4.00.**

An important recent booklet for catadioptric enthusiasts is **Construction of a Maksutov Telescope,** by Warren I. Fillmore. It describes the ordering, grinding, testing, and assembling of the optical and mechanical parts of a Gregory-Maksutov 6-inch f/15 telescope, including ideas for accessories. Printed by the photo-offset process, the monograph is illustrated with many photographs and drawings showing equipment tests, ground lens curves, Ronchi patterns, and the completed telescope. *29 pages,* **$1.00.**

Other Sky booklets: **Splendors of the Sky,** *36 pages, 66 illustrations,* 50 cents; **Relativity and Its Astronomical Implications,** by Philipp Frank, 75 cents; **How To Build a Quartz Monochromator** for Observing Prominences on the Sun, by Richard B. Dunn, 50 cents; **The Story of Cosmic Rays,** by W. F. G. Swann, 75 cents.

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BOOKS AND THE SKY

PHYSICAL SCIENCE

Donald S. Allen and Richard J. Ordway. D. Van Nostrand, Inc., Princeton, N. J., 1960. 825 pages. $8.25.

DURING the past decade many colleges and universities have established courses in physical science for the nonscience major. The philosophy underlying these general presentations has been that the nonscientist can benefit more from a broad look at the entire field of physical science than from detailed study of one particular area.

From their inception, such physical science courses have encountered a basic difficulty — lack of a suitable text. A number of books attempting to fill this void have appeared within the last few years. Allen and Ordway's *Physical Science* is a recent one.

In their preface the authors state that their intention is not to cover physical science in its entirety. Rather, they limit the discussion to a selected group of significant topics. Each is treated with some thoroughness, the historical approach lending continuity and interest. This reviewer feels that Allen and Ordway have not been completely successful in achieving their goals.

The first 14 chapters (291 pages) cover physics and chemistry, followed by seven chapters of 154 pages on astronomy. The most important topics in meteorology are highlighted in 59 pages, and a concluding 10-chapter section on geology occupies 270 pages. The amount of space devoted to each field probably reflects the major disciplines of the two authors, chemistry and geology.

In the section on physics and chemistry an attempt has been made to integrate these two fields in a comprehensive fashion. Each new topic is introduced by a historical sketch, which leads naturally to the fundamental concept under discussion. The reader gets a feeling of the manner by which scientists through the ages have proceeded to solve problems.

The topics of physics are handled very well and in a manner that should arouse the interest of nonspecialists. On the other hand, the treatment of chemistry is not so successful. In spots it is poorly written, and lapses into the detailed technicalities of balancing chemical equations rather than stressing fundamental principles. There is a lack of clarity and some terms are inadequately defined, even though one of the authors is a chemist, as already noted.

The chapters on meteorology and geology are generally well written and developed in a logical fashion, though not strictly historically. The only real criticism one can make about these sections is that lengthy captions are used for illustrations and diagrams. Frequently, these captions repeat the material found in the adjacent text.

In striking contrast to the other parts of *Physical Science,* the chapters on astronomy show a general lack of organization and logical development. Allen and Ordway have attempted to cram too many topics into a limited space; careful editing by an astronomer would have been of great benefit. Some concepts are discussed before preliminary definitions and ideas. As an example of this difficulty, the use of the period-luminosity relation to determine stellar distances is introduced long before variable stars themselves are presented.

An example of incorrect balance in the selection of material is the discussion of tests for the earth's motions. Although a thorough coverage of the Foucault pendulum proof is given for rotation, the topic of revolution is dismissed in two sentences without a single proof. Furthermore, the terms "rotation" and "revolution" are used incorrectly in a number of places.

The chapters on the planets, astro-

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THE EXPLORATION OF SPACE — Robert Jastrow, editor. 160 pages. **$5.50**
ADVANCES IN THE ASTRONAUTICAL SCIENCES, Vol. 6 — H. Jacobs and E. Burgess, editors. 898 pages. **$22.50**
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nomical instruments, stars, nebulae, and galaxies, are primarily a recitation of facts. There is very little discussion of how the facts were obtained or why astronomers have confidence that certain ones represent the actual nature of the universe. A physical science teacher may encounter difficulties in using the astronomy section of this textbook.

The volume is beautifully produced with type that is restful to the eyes. The diagrams are excellent and there are numerous illustrations. Some of them, such as a full-page photograph of a hydrogen bomb explosion, could be omitted without affecting the continuity of the text.

ROBERT T. MATHEWS
Goodsell Observatory
Carleton College

THE ROTATION OF THE EARTH

Walter H. Munk and **Gordon J. F. MacDonald.** Cambridge University Press, New York, 1960. 323 pages. $13.50.

ASTRONOMERS can well be pleased with the precision with which the earth rotates. Even so, there are slight changes and wobbles, and investigating them involves a wide range of interesting branches of geophysics and astronomy. A wealth of information hides behind slight effects — the moon's tidal force, motions of the atmosphere, variations in sea level, continental movements, motions in the earth's core. These and some other factors are considered in Munk and MacDonald's discussion, with a quite unusual degree of thoroughness, clarity, and precision.

Since observational evidence comes from a great variety of sources, it has been very difficult in the past to consider the earth's rotation in a unified fashion. Astronomical information about changes in the length of the day and variations of latitude form the main modern data. In addition, there are historical accounts of eclipses — whose occurrences are related to speed of rotation — and geological clues. The direction that the rotational axis takes relative to the body of the earth is indicated by the magnetization of ancient rocks. There is also evidence from climatic changes; the movements and unsteady dispositions of masses on the earth give observational material on which to base an analysis of these effects.

Tides, winds, atmospheric circulation, the ocean level, pressure distributions in the atmosphere, and height of the water table are among the subjects discussed. Observational data can be used to specify limits for such quantities as the plasticity of the earth as a whole, the fluidity of the core, and internal motions.

The book is by no means easy reading. Some knowledge of dynamics and elasticity is required, and a willingness to follow the many lines of carefully argued

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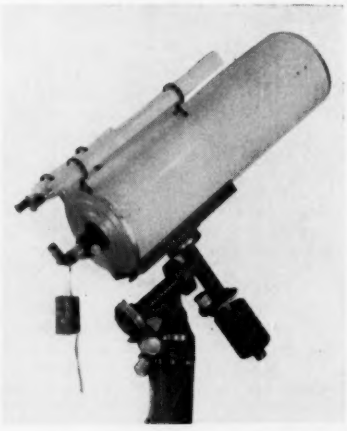

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evidence. However, it is an excellent presentation of all that is known concerning the speed of the earth's rotation and the direction of its axis. If major conclusions cannot be very definite, this is due to inadequacy of evidence; the authors very properly point out the great range of possibilities that cannot be excluded.

This perhaps is the most important function of a book that compiles information from many sources. For example, it is permissible to think of the earth's core as being formed in a few billion years by the inward draining of heavier materials in the mantle. The consequent rate of decrease of the moment of the earth's inertia would fit the observational data on the rate of change of longitude of sun and moon. We can also think that the body of the earth can move through large angles relative to the rotation axis. There appears to be nothing to prevent one from interpreting geological, magnetic, or climatological data in terms of this large-angle polar wander in geological times.

The book was awarded the 1959 monograph prize of the American Academy of Arts and Sciences in the field of physical and biological sciences. It should be used as an example in scientific writing.

THOMAS GOLD
Cornell University

ATOMS TO GALAXIES

James Stokley. Ronald Press Co., New York, 1961. 360 pages. $6.00.

HERE is a book for any reader who wants to learn more about astronomy and its fringes than he knows from, say, a high school general science course. Well written by a former director of the Fels and Buhl planetariums, who is now a professor of journalism at Michigan State University, its approach is direct. Mr. Stokley has but one aim — to convey information.

As the title implies, the reader is first introduced to the elementary history of the atom; then he is told about Niels Bohr's concept of atomic radiation, the Doppler effect, and the way in which telescopes gather light. In natural sequence there follows a chapter on radio astronomy, with nearly three pages on Project Ozma. Finally, before the sun and planets are treated, 11 pages describe energy production in stars.

Perhaps the best part of the book is Chapter 6, "The Earth." I believe Mr. Stokley has here filled a serious hiatus in many books on astronomy, at all reader levels. Though his coverage is necessarily brief, he includes the following topics in 33 pages: tilt of the earth's axis, its mass, earthquake waves, the core, crust composition, the mantle, gold in the sea, shifting currents, an ice-free Arctic Ocean, atmospheric structure, causes of the aurora, radiation belts, and Project Argus.

In comparison with the Earth chapter, the one on travel in space seems commonplace and prosaic, but perhaps only because we read so much about spaceflight these days as to be bored by another superficial review. Nevertheless, this chapter serves its introductory purpose, as do those that precede it.

But is it right that the stars and our own and all other galaxies are covered in only 55 pages? There is hardly room for definitions of the terms used, and the author creditably does not avoid the normal technical words of astronomy. He has had to be very brief in treating a major, most important part of astronomy. If the volume, in a new edition, cannot be expanded to bring the sidereal universe into its true proportion, then Mr. Stokley might well write a companion book on the subject.

Atoms to Galaxies, were it twice as long and as well written, would still not lose reader interest. But could its cost be kept near the popular level? The typesetting, paper, and printing of the present volume are excellent, yet there are indications that the publisher has pinched pennies. Although the line illustrations cover most salient points of the text, they lack uniformity, as they are almost all from other publications. The halftones are bunched together in the book's center, usually two on a page, where their scale is small and they don't do the job expected of pictures in an astronomy book. It is difficult to understand why, being bunched, they could not have had the advantage of letter-press printing, instead of photo-offset.

Incidentally, only two of these 31 photographs are *not* from Mount Wilson and Palomar Observatories. We hope that in the next edition Mr. Stokley will obtain pictures from other observatories of the world, since too many newcomers to astronomy seem to think the 200-inch is the only telescope astronomers use these days. In fact, an added chapter on telescopes and instruments in general, with emphasis on the international aspects of astronomy, would help round out the book.

C. A. F.

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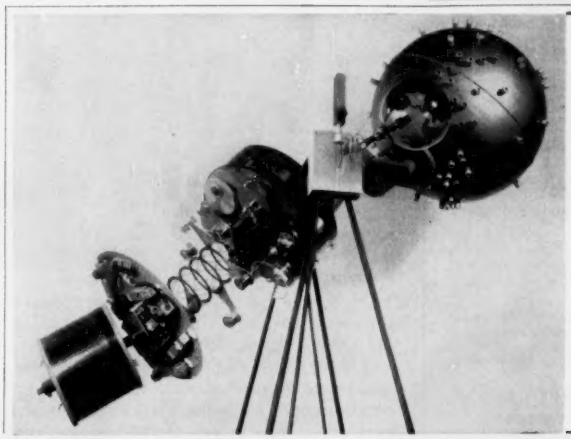

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NEW BOOKS RECEIVED

ADVANCES IN THE ASTRONAUTICAL SCIENCES, Vol. 6, *Horace Jacobs* and *Eric Burgess*, editors, 1961, *Macmillan*. 898 pages. $25.00.

Fifty-seven research papers given at the sixth annual meeting of the American Astronautical Society in January, 1960, cover space communication, propulsion, guidance and control, space medicine, flight mechanics, vehicle design, re-entry problems, and space physics.

SPACE ASTROPHYSICS, *William Liller*, editor, 1961, *McGraw-Hill*. 272 pages. $10.00.

Astronomical problems as studied from above the earth's atmosphere by rockets, artificial satellites, and balloons are discussed. These 1959-60 lectures at the University of Michigan by visiting scientists provide a semitechnical survey of the instrumentation, experiments, and theory of space astrophysics.

CHANGING VIEWS OF THE UNIVERSE, *Colin A. Ronan*, 1961, *Macmillan*. 206 pages. $3.95.

First in a series that aims to provide an up-to-date popular picture of astronomy, this history traces the development of ideas about the cosmos from prehistory to the 20th century. The author is director of the historical section of the British Astronomical Association.

THE TELESCOPE AND THE WORLD OF ASTRONOMY, *Marvin F. Riemer*, 1961, *Scope Instrument Corp.*, Mamaroneck, New York, N. Y. 211 pages. $3.95.

In this introductory book, the beginner in astronomy is urged to observe the skies for himself. The appearance of the constellations, astronomical equipment, and elementary photographic techniques are described, with constellation charts and tables of observing data included.

SCIENCE IN SPACE, *Lloyd V. Berkner* and *Hugh Odishaw*, editors, 1961, *McGraw-Hill*. 458 pages. $7.00.

Twenty scientists review the opportunities for new research afforded by space probes. The astronomical sections consist of chapters on the moon and planets by H. C. Urey, and on solar, galactic, and extragalactic problems by Leo Goldberg and E. R. Dyer, Jr. The presentation is aimed at nonspecialist readers.

MAN AND THE MOON, *Robert S. Richardson*, commentator, 1961, *World*. 171 pages. $6.50.

Professional and amateur astronomers have contributed chapters to a popular anthology of facts and conjectures about the moon and man's chances of living on it. Twenty-five plates include several paintings by Chesley Bonestell.

SATELLITE ENVIRONMENT HANDBOOK, *Francis S. Johnson*, editor, 1961, *Stanford University Press*. 155 pages. $5.50.

Brief surveys of the existing data on the upper atmosphere, the ionosphere, penetrating radiation, micrometeorites, and similar topics, present a picture of the environment through which artificial satellites travel.

METHODS OF CELESTIAL MECHANICS, *Dirk Brouwer* and *Gerald M. Clemence*, editors, 1961, *Academic Press*. 598 pages. $15.50.

This textbook for graduate students and advanced undergraduates is a comprehensive summary of celestial motions resulting from gravitational forces. The treatment of orbit determination and perturbations is preceded by chapters on co-ordinates, mathematical techniques, and the reduction of observations.

METEOR SCIENCE AND ENGINEERING, *D. W. R. McKinley*, 1961, *McGraw-Hill*. 309 pages. $12.50.

A leading Canadian expert on meteors summarizes modern techniques for their study, with special emphasis on radar observations. His discussion is aimed at readers who, though not meteor specialists, have a scientific or engineering background.

TEXT-BOOK ON SPHERICAL ASTRONOMY, *W. M. Smart*, 1960, *Cambridge University Press*. 430 pages. $3.95, paper bound.

A wide variety of problems involving astronomical co-ordinates, time, eclipses and occultations, photographic measurements, navigation, and binary star orbits are concisely treated in this well-known textbook, first published in 1931. This is a reprint of the fourth edition (1944).

HANDBUCH DER AEROLOGIE, *Walter Hesse*, editor, 1961, *Akademische Verlagsgesellschaft Geest und Portig K.-G.*, Sternwartenstrasse 8, Leipzig C 1, East Germany. 897 pages. DM 80.

Old and new methods of atmospheric research are reviewed in this German-language monograph, augmented by extensive bibliographies and numerous diagrams and tables.

AN INTRODUCTION TO CELESTIAL MECHANICS, *Theodore E. Sterne*, 1960, *Interscience*. 206 pages. $4.50.

General methods rather than particular problems are featured in this brief introduction to the mathematical study of solar system motions. An extended section is devoted to the celestial mechanics of artificial satellites. This volume is the ninth of the Interscience tracts on physics and astronomy.

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SS08A Ecliptic-based star map — with equatorial grid and names
SS08 Ecliptic-based star map — with equatorial grid, **without** names
SS05 Nine-inch protractor on paper — for planet orbit drawings
SS11 Inner planet chart — orbits of Mercury, Venus, Earth, Mars
SS12 Outer planet chart — orbits of Mercury to Saturn
SS01A Special rectangular co-ordinate paper — for star maps
SS02 Polar co-ordinate paper — for circumpolar star maps
SS00 Aitoff's equal-area projection of the sphere — 13 inches wide

Price for each item listed above: 1 to 9 sheets, 10 cents each; 10 to 24 sheets, 8 cents each; 25 to 99 sheets, 6 cents each; 100 or more, 5 cents each.

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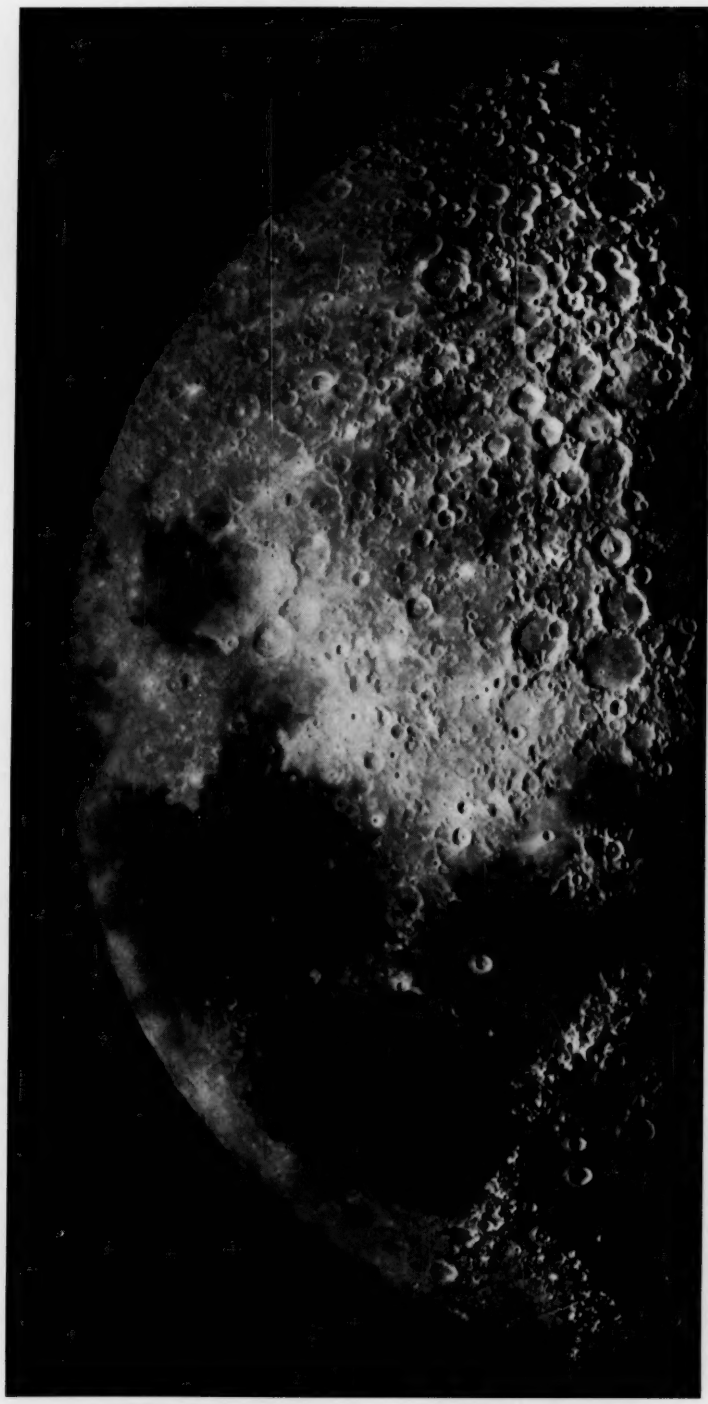
BUY, SELL, Trade: Cameras, lenses, telescopes, amateur radio equipment. Denson Electronics, Box 85, Rockville, Conn.



The race to space may be won in your own school with a Tinsley Telescope

There are uncountable universes waiting to know the mastery of the Earthborn scientist. Perhaps he will be the dedicated scholar in the first row of your class, or the boy just behind him to the right. The Tinsley 12-inch Telescope will open the secrets of galaxies upon galaxies to them, and to all the young minds who must absorb – and learn to live with – concepts unimaginable to their grandparents.

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$4,850.00, F.O.B. BERKELEY

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An Unusual Buy!

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Excellent for deep-sky and Milky-Way observation.

Brand new! Crystal-clear viewing — 7 power. Coated optics. An excellent night glass — recommended for satellite viewing. Individual eye focus. Exit pupil 7 mm. Approx. field at 1,000 yds., 376 ft. Carrying case included. American 7 x 50's usually are $195.

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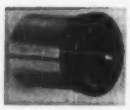
Wide, flat field — better correction under high magnification — excellent eye relief.



The orthoscopic eyepiece is one of the most important and best corrected eyepieces for astronomical work. These are of a four-element design, with coated lenses, and are standard 1¼″ outer diameter, precision made of chrome-plated brass and aluminum.

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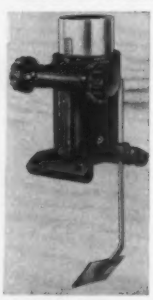
Rack-&-Pinion Eyepiece Mounts



Real rack-and-pinion focusing with variable tension adjustment; tube accommodates standard 1¼″ eyepieces and accessory equipment. Lightweight aluminum body casting (not cast iron); focusing tube and rack of chrome-plated brass; body finished in black wrinkle paint. No. 50,077-Y is for reflecting telescopes, has focus travel of over 2″, and is made to fit any diameter or type tubing by attaching through small holes in the base. Nos. 50,103-Y and 50,108-Y are for refractors and have focus travel of over 4″. Will fit our 2⅞″ I.D. and our 3⅞″ I.D. aluminum tubes, respectively.

For Reflectors
Stock #50,077-Y..(less diagonal holder)....**$8.50 ppd.**
Stock #60,049-Y..(diagonal holder only).... **1.00 ppd.**

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Stock #50,103-Y..(for 2⅞″ I.D. tubing)...**$12.95 ppd.**
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. . . Point It Out With Projected Arrow

Ideal for pointing to interesting features on movie and slide projection screens. Excellent lecture tool. For teacher use on maps, etc. Flashlight focuses an arrow where you point it.

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Make Your Own CLOCK DRIVE — ONLY $4.00

Excellent value for the serious amateur. With this motor you can make your own clock drive for about ⅓ the cost of a purchased one. Type 117-P Cramer motor (without clutch), left rotation, 1/15 r.p.m. 115 volts, 60 cycles, 2.7 watts, with a ⅜″ shaft plus an extra 1½″-long shaft, setscrews, and directions for adapting to your telescope.

Stock #60,205-Y.....$4.00 ppd.

Take Pictures Through Your Telescope with the EDMUND CAMERA HOLDER for TELESCOPES

Bracket attaches permanently to your reflecting or refracting telescope. Removable rod with adjustable bracket holds your camera over scope's eyepiece, and you're ready to take exciting pictures of the moon. You can also take terrestrial telephoto shots of distant objects. Opens up new fields of picture taking!

SUN PROJECTION SCREEN INCLUDED

White metal screen is easily attached to holder and placed behind eyepiece. Point scope at sun, move screen to focus . . . and you can see sunspots!

All for the low, low price of $9.95

Includes brackets, 28¾″ rod, projection screen, screws, and directions. Aluminum; brackets black crinkle painted.

Stock #70,162-Y.....$9.95 ppd.

PRISM STAR DIAGONAL

For comfortable viewing of stars that are high in the sky and overhead. Fits refracting telescopes using standard-size (1¼″ O.D.) eyepieces, or you can make an adapter for substandard refractors. Contains an excellent high-quality aluminized right-angle prism. The tubes are satin chrome-plated brass. Body is black wrinkle cast aluminum. Optical path length of the system is about 3½″.

Stock #70,077-Y.....$12.00 ppd.

Operate Your Clock Drive From a 12-Volt Auto Battery

These small inverters supply 110-volt, 60-cycle electricity from your car battery to operate your clock drive anywhere. (Can also be used to operate electric shaver.) 20-watt rating. Size: 2½″ x 2½″ x 3″, 2 lbs.

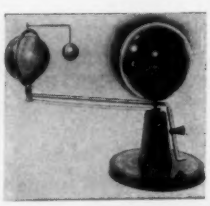
Stock #50,346-Y...(for 12-volt battery)...**$14.95 ppd.**

NEW SQUARE-SHAPED RETAINING RINGS

Set of 20 only $1.25

Custom-designed square-cross-section retaining rings provide far greater bearing surface than the usual round variety. Made of special carbon steel, these retaining rings really hold your lenses in position. Set includes four each of five different sizes: .618″ O.D. x .035″ sq.; .878″ O.D. x .039″ sq.; 1.136″ O.D. x .055″ sq.; 1.400″ O.D. x .062″ sq.; and 1.665″ O.D. x .071″ sq. Complete set provides superior results previously unobtainable, and fits practically all available tube sizes.

Stock #60,207-Y.....$1.25 ppd.

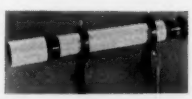


THE PLANETARIUM PORTRAYS THE FASCINATING STORY OF EARTH IN ACTION

Here is the story of cosmic motions — how the moon revolves around the earth, and the earth around the sun, with our planet rotating simultaneously. With this instrument, the observer sees a three-dimensional moving demonstration of how seasons, day and night, and moon phases occur. This handsome gear-and-chain-driven unit is supported by a smartly finished wood base. The sun is 6″ in diameter, and the earth is 4″. Planetarium stands 12″ high, is 8″ wide; arm is 18″ long. A completely illustrated, delightfully informative handbook included.

Stock #70,415-Y.....$29.95 ppd.

6X FINDER TELESCOPE



Has crosshairs for exact locating. You focus by sliding objective mount in and out. Base fits any diameter tube — an important advantage. Has 2 holders, each with 3 centering screws for aligning with main telescope. 20-mm.-diameter objective. Weighs less than ½ pound.

Stock #50,121-Y.....$8.00 ppd.

TELESCOPE LIGHTING SYSTEM

Help Preserve Your Night Vision

Fits any telescope; takes one size D flashlight battery. Case fastens to tripod leg with wing nut and clamp. Two grain-of-wheat lamps and housings with 39″ cords. One lamp rheostat controlled. By drilling a small hole in finder tube at the plane of the reticle, you can illuminate the crosshairs, controlling their brightness. Other lamp stays at constant brightness so you can illuminate your setting circles, check eyepieces, examine charts, or make notes.

Stock #50,219-Y.....$2.95 ppd.

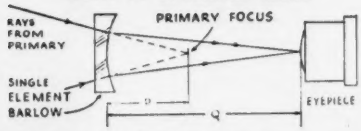
EDMUND SCIENTIFIC CO.

THE ORIGINAL GOODWIN RESOLVING POWER BARLOW

For many years, this achromatic coated Barlow lens has been the pride and joy of serious astronomers. Due to the death of the designer, Mr. Frank Goodwin, it has not been available for the past two years. NOW we can offer these lenses, in exact accordance with the original specifications. Remember, this Barlow is achromatic, coated, mounted in a blackened tube, and as optically perfect as only precision craftsmen can make it. Complete with instructions, in a 4"-long adapter tube for standard 1¼" eyepieces.

Stock #60,122-Y.....**$23.50 ppd.**

DOUBLE AND TRIPLE YOUR TELESCOPE'S POWER WITH A BARLOW LENS



WHAT IS A BARLOW? A Barlow lens is a negative lens used to increase the power of a telescope without resorting to very short-focal-length eyepieces, and without the need for long, cumbersome telescope tubes. Referring to the diagram above, a Barlow is placed the distance P inside the primary focus of the mirror or objective. The Barlow diverges the beam to a distance Q. This focus is observed with the eyepiece in the usual manner. Thus, a Barlow may be mounted in the same tube that holds the eyepiece, making it very easy to achieve the extra power. The new power of the telescope is not, as you might suppose, due to the extra focal length given the objective by the difference between P and Q. It is defined as the original power of the telescope times the quotient of P divided into Q.

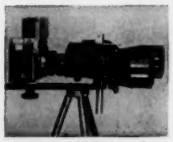
Beautiful chrome mount. We now have our Barlow lens mounted in chrome-plated brass tubing, with special spacer rings that enable you easily to vary the power by sliding split rings out one end and placing them in other end. Comes to you ready to use. Just slide our mounted lens into your 1¼" I.D. tubing, then slide your 1¼" O.D. eyepieces into our chrome-plated tubing. Barlow lens is nonachromatic.

Stock #30,200-Y...Mounted Barlow lens....**$8.00 ppd.**

BINOCULAR-TO-CAMERA HOLDER

For Exciting Telephoto Shots

Will fit any camera



Bring distant objects 7 times nearer with a 35-mm. camera, 7 x 50 binocular, and our BINOCULAR-TO-CAMERA HOLDER. Ideal for photographing constellations, star clusters, the moon, as well as cloud formations, wildlife, vistas. Camera and binocular attach easily. Use any binocular or monocular — any camera, still or movie. Take color or black-and-white. Attractive gray crinkle and bright chrome finish, 10" long. Full directions for making telephoto pictures included.

Stock #70,223-Y.....**$11.50 ppd.**

MORE POWER FROM YOUR JAPANESE TELESCOPE

Mounted Barlow for Japanese Telescopes

By inserting this single-element lens in the eyepiece end of your Japanese telescope, and putting your regular eyepiece in the end of the Barlow tube, you can increase your telescope's power two or three times. Thus, instead of 60x, you will get 120x or 180x. Barlow is mounted in two pieces of telescoping brass tubing each 4" long, satin-chrome plated on the outside. Inner diameter of large tube and outer diameter of small tube are 0.965", the standard size for most Japanese telescopes. Measure yours before ordering. 0.965" is approximately 31/32" or 24.5 mm.

Stock #30,370-Y.....**$6.00 ppd.**

Learn Astronomy The "Fun" Way

53 STAR & PLANET FLASH CARDS

Complete Set Only $1.00

Make learning fun and easy. Just look at the picture, then turn the card for identification — full details given on the back. Set includes 29 constellation cards, 10 on the solar system, 10 star cards, and 4 of other celestial objects.

Stock #60,210-Y.....**$1.00 ppd.**

Suppress Internal Reflection

FLOCK-PAPER TUBE LINING

Superior to Dead-Black Flat Paint

Special paper with a black velvetlike surface that absorbs light and prevents unwanted reflections and glare. Ideal as a screen on which to project star images for a realistic effect. Easily glued or cemented inside your tube. FEATURED in April, 1961, *Review of Popular Astronomy* (page 13) by G. R. Wright. Comes in sheets, 27" x 36".

Stock #60,068-Y.....per sheet.....**$1.00 ppd.**

STAR TIME CALCULATOR

This handy slide rule automatically makes the conversion from star or sidereal time to standard time. Saves the amateur astronomer the time and trouble of calculations. Size: 10½" x 3⅜"; plastic-coated cardboard.

Stock #40,399-Y.....**$1.50 ppd.**

CLOCK-DRIVEN EQUATORIAL MOUNT ON PEDESTAL BASE IDEAL FOR YOUR 6" OR 8" REFLECTOR

Accurate electric clock drive and heavy-duty mounting. Operates on household current. Follows stars smoothly. Pedestal is 24" high. Polar-axis shaft diameter 1". Setting circles included.

Stock #85,111-Y.....**$74.50** f.o.b. Barrington, N. J.

Same mount and clock drive on 32" hardwood tripod.

Stock #85,081-Y.....**$69.00** f.o.b. Barrington, N. J.

Same mount on metal pedestal, no clock drive.

Stock #85,108-Y.....**$45.00** f.o.b. Barrington, N. J.

Same mount on tripod, no clock drive.

Stock #85,023-Y.....**$39.50** f.o.b. Barrington, N. J.

WHIRLING WONDERS

Wonderful World of Whirling Wheels

Here's a new adventure in optical impressions — created by the magical effect of these fascinating rotating disks. In addition to weird shapes and fantastic "after images," this kit demonstrates "stop-motion" stroboscopic principles, "off-center" focus, and even hypnotism. Kit includes 13 disks approximately 5" in diameter, battery holder, rheostat, small motor mounted on bracket, bulb, socket, plug, and complete booklet of instructions and experimental uses.

Stock #70,414-Y.....**$9.95 ppd.**

Mounted Ramsden Eyepieces

Standard 1¼" Diameter

Our economy model, standard-size (1¼" O.D.) eyepiece. We mounted two excellent quality plano-convex lenses in black anodized aluminum barrels instead of chrome-plated brass to save you money. The clear image you get with these will surprise you. Directions for using short-focal-length eyepieces are included with both the ¼" and ½" models.

Stock #30,204-Y.....¼" focal length.....**$4.75 ppd.**

Stock #30,203-Y.....½" focal length.....**$4.50 ppd.**

SETTING CIRCLES TO FIT YOUR EDMUND TELESCOPE OR TELESCOPES WITH SIMILAR-SIZED MOUNTS

A — Heavy-Duty

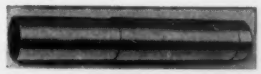
B — Light-Duty

(A) FOR HEAVY-DUTY MOUNT (fits Edmund 6" reflector, 4" refractor). Black plastic. Hour circle has two scales, bottom 0 to 24 hrs., top 0-6, 6-0, etc. Declination circle has numbers every 10°, lines each degree. All filled white. Hole is 1.9"; 3" outer diameter. Two pointers with 2¼" holes.

Stock #60,188-Y.....**$3.00 ppd.**

(B) FOR LIGHT-DUTY MOUNT (fits Edmund 4¼" reflector, 3" refractor). Black plastic, scales same as above. 1"-diameter hole; 3" outer diameter. Two pointers with 1¼"-diameter holes.

Stock #60,187-Y.....**$3.00 ppd.**



NOW! LENS ERECTOR FOR TERRESTRIAL VIEWING WITH YOUR REFLECTOR

This Edmund development adds real convenience to viewing objects on the earth. Just put the lens erector in your eyepiece holder, insert eyepiece, and focus normally. You see everything right side up and correct as to left and right. Made of polished chrome-finished brass telescoping tubing that will fit any standard 1¼" eyepiece holder. Tubing is 9½" long and slides 3" into eyepiece holder. Erecting system consists of two coated achromats.

Stock #50,276-Y.....**$9.95 ppd.**

GIANT ERFLE EYEPIECE 1½" F.L.

War-Surplus Bargain — Gov't. Cost Approx. $100

Large telescopes should have one of these for low-power viewing. Apparent field of view 65°. Also use with our 24"-focal-length Aerial Camera lens to make a 16-power wide-field telescope or a 27-power scope with one of our 40"-focal-length Aerial Camera lenses. Low-reflection-coated, 5-element lens system. Field lens of Eastman Kodak's rare-earth glass for better aberration correction. Has diopter scale. Smooth focusing, ⅜" movement. Outside diameter of attaching threads, 3" — 32 threads per inch. Clear aperture of eye lens 2", field lens 1-25/32". Weight 3½ lbs.

Stock #50,091-Y.....**$9.95 ppd.**

ADAPT GIANT ERFLE TO STANDARD TELESCOPE EYEPIECE SIZE

This adapter lets you use our Giant Erfle with any telescope having a standard 1¼"-diam. eyepiece holder.

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GLEANINGS FOR ATM's

CONDUCTED BY ROBERT E. COX

Cleaning the Lens of a 12¼-Inch Refractor

RESTORATION of the much-neglected 12¼-inch Clark refractor at Morrison Observatory, Fayette, Missouri, has consumed a year's spare-time effort of student Bill Schoening, under the supervision of Richard Fawcett, director of the observatory. The entire mounting has been thoroughly cleaned and oiled, and a 6-inch transit circle was also put in working order.

Permission to clean the large grime-coated lens was not granted by the president of Central College, however, until two local telescope makers, Harry Brown and the undersigned, agreed to help. Realizing the responsibility of handling such a famous and valuable lens, we planned every step of our procedure with great care.

First, the objective was detached from the upper end of the telescope tube by taking out three screws of the push-pull adjusting system. The cell and lens were then surrounded by more arms than an octopus has, and carried to the room where the cleaning equipment was set up.

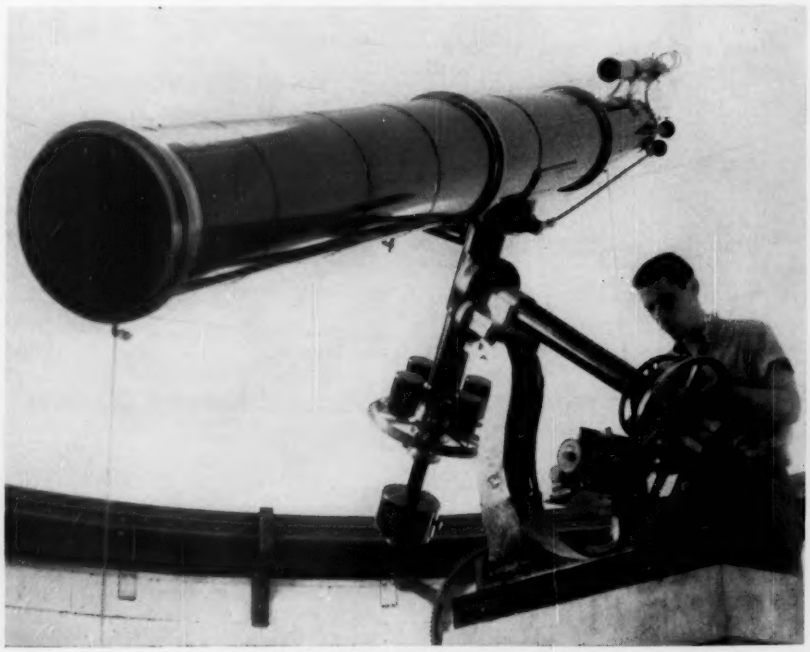
The objective was centered on a towel-covered pedestal made of a pile of books. The three screws holding the retaining ring in place over the crown element were removed, so the cell could be slid down past the glass and books onto the table. The retaining ring was then lifted off, revealing a thick layer of grime, most of which was blown off by a bulb syringe. Then the crown glass was carefully grasped by its edge and lifted from the flint element.

The spacers — three small pieces of tin foil — were stuck so tightly to the glass surface that it was decided to leave them in place during the cleaning operation. The edge separation of the two 12¼-inch elements is surprisingly small, and we had to take care not to alter it on reassembly.

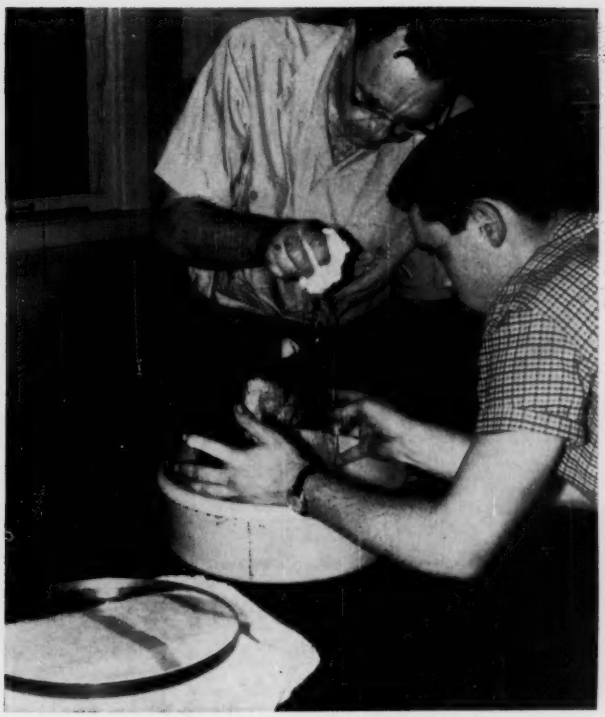
Each lens component was cleaned by lowering it into a rubber pan with a ball of cheesecloth in the center to keep it off the bottom. The inside surface was placed down, since the exposed parts were much too dirty to touch anything. The glass was soaked several times in fresh solutions of Dreft in distilled water, and then a large cotton ball was soaked in solution and squeezed over the surface. This running stream of water helped loosen stubborn dirt. Finally, a new change of water and Dreft was made, and a clean cotton ball immersed in the pan for gently swabbing the surfaces of the lens.

The inside or flint element was easier to clean than the crown, as it had not become so dirty. The glass lenses became quite slippery while being cleaned, necessitating extreme care. Meanwhile, Mr. Schoening cleaned the brass cell and polished its exterior, covering the finished surfaces with a quick-drying coat of clear lacquer.

We had achieved marked improvement



The 12¼-inch lens of the Alvan Clark refractor at Morrison Observatory, Fayette, Missouri, was readily removed for cleaning by turning the telescope toward the floor, as shown in this picture. The refurbished instrument, which has a 3-inch f/17 finder, is being checked by Bill Schoening.

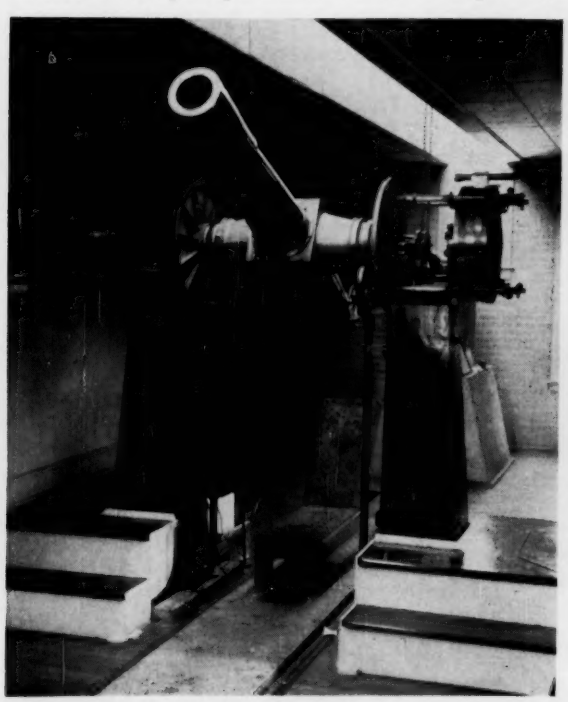


Two steps in the lens-cleaning process. At the left, the retaining ring has been removed from the lens cell, which was lowered to the table top. Loose dirt is being blown off the crown element with a bulb syringe. At the right, the crown glass has been lifted away from the flint and placed in one of many successive cleansing baths.

in the transparency of the glass. It was apparent, however, that time and weather had bloomed the inside of the crown, giving it a faint milky white stain over part of its surface. On reassembly, we found the performance commensurate with what we might expect from a Clark objective.

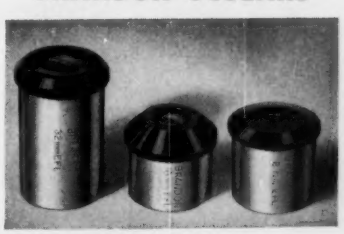
The 12¼-inch f/17 refractor was erected in 1875 as the principal instrument of Morrison Observatory, founded with funds provided by Miss Berenice Morrison. This instrument was actively used during the next decade by two well-known astronomers, C. W. and H. S. Pritchett, for observations of double stars, comets, planets, and satellites. In 1879 it was used for micrometer measurements of Mars' moons Phobos and Deimos, an unusual feat with this aperture, and a tribute to the optical craftsmanship of Alvan Clark and Sons. The original cost of the instrument was $6,000.

R. E. C.



This transit circle was manufactured by Troughton and Simms of London, and mounted at the Morrison Observatory in 1877. The objective lens is six inches in diameter, with a focal length of 77 inches. Powers of 100 and 170 were used in observing transits of stars. Under the telescope, between the piers, is the observer's couch. All photographs with this article are by Robert E. Cox.

BRANDON OCULARS



These orthoscopic oculars are the choice of the amateur as well as the professional astronomer. Seven sizes available: 4-mm., 6-mm., 8-mm., 12-mm., 16-mm., 24-mm., and 32-mm. focal lengths. Standard 1¼" outside diameter.

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Adler Planetarium, 900 E. Achsah Bond Dr., Chicago 5, Ill.

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4" f/8	**$42.00**
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All mirrors made of PYREX-brand glass.

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Finest quality. They are precision machined, mounted in standard 1¼" outside diameter barrels. Can be taken apart for cleaning. Designed to give sharp flat field clear to edge.

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Kellner 30-mm. f.l. (1-3/16")	**12.50**
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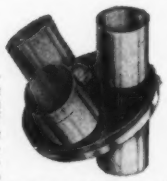
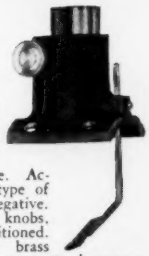
Revolving Turret



The Criterion Revolving Turret holds three eyepieces so that, as desired, the power of the telescope can be changed by merely turning the turret to a different ocular. Click stop insures positive and accurate positioning of each eyepiece. Turret holds eyepieces of standard 1¼" outside diameter. Fits into the holder of any refractor or reflector telescope that uses 1¼" eyepieces. Requires no alteration or adjustment and can be attached as easily as putting eyepiece into scope. Made of brass and aluminum with polished chrome-plated barrels.

Cat. #SRT-350..... **$14.50**

Rack-and-Pinion Eyepiece Mount



The most mechanically perfect focusing is by rack and pinion. This mount takes standard 1¼" eyepieces. Full 3½" of travel — more than ever before. Accommodates almost any type of eyepiece — positive and negative. Two knurled focusing knobs, variably tensioned and positioned. Solid cast-metal sliding brass tube — close tolerance prevents looseness. Mount aligns itself to any type tube. Four mounting holes, nuts and bolts included. Eye mount has square-rod-type diagonal holder which prevents loose alignment and vibration. Rod tempered to minimize temperature changes. Adjustable for 3" to 8" scopes, also 12" scopes if so specified at no extra cost. Order one or more of the complete eyepieces described below at the same time you send for this rack-and-pinion device, which accommodates any of our eyepieces perfectly.

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EFFORTS by those interested in introducing astronomy to the public of Idaho City, Idaho, have resulted in the Pineview Observatory. This two-story structure, built by amateurs, cost only about $250.

The building's foundation is a solid slab of concrete, 16 inches deep, and the native-stone walls of the first floor are inset here and there with glass brick to let in light. The second-story floor rests on 12-by-12-inch timbers, braced with angle irons. This serves as the observing platform, and also carries a 4½-foot wall supporting the dome.

In this view of the east side of the Pineview Observatory at Idaho City, Idaho, the slit is open, as for observing. One part swings outward, another opens overhead. Access to the observatory is from the northeast; the building features an outdoor observing platform on the second-floor level and two telescopes within the dome. Photograph by John Williams.

We adapted a standard metal silo dome, bolting the ribs to a circle of angle iron, to whose underside are fastened ball-bearing castors. The dome rides on another angle-iron circle attached to the wall, and is easily turned by hand. Two hinged panels cover the dome slit, one of them opening directly overhead.

A catwalk with a pipe railing runs around two sides of the second story. Access is by steel steps taken from a dismantled gunboat.

Inside the dome are two small telescopes, a refractor and a reflector, and the first-floor storage room contains a compact, up-to-date astronomical library. Pineview Observatory is made available without charge for the instruction of children attending camps in nearby recreation areas.

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Idaho City, Idaho

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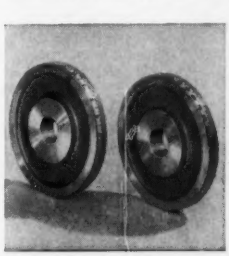

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The Palomar-type shutters are each 16″ wide, and open to 30″. Because the upper sections tended to stick when opening, rope attached to each leaf was run through pulleys to form a system similar to household draw drapes.

The dome can be turned through 360 degrees on its 16 rubber-tired trucks, with six extra trucks working horizontally against the track to keep it in place. A stairway 2′ wide gives access to the observing platform, which is 12′ square. The lower section of the staircase, leading up to a small platform, can be retracted by means of a hand-operated boat winch.

The amount of city light in this district of Chicago called for a dome whose slit opening could be kept very narrow during observing. At the left is the retractable staircase, with its railing of $\frac{1}{2}$-inch gas pipe. The high location of the platform exposes the dome to wind, but it has stood up well. Photograph by the author.

My telescope has a 6″ concrete pier, molded with stovepipe and set 3′ below the garage floor, not touching the structure. I find it fairly steady, but it should be thicker and set deeper.

This serviceable observatory cost about $550. The open-construction platform holds no heat, eliminating waiting for thermal equilibrium to be established. The structure has withstood 16″ snowfalls and winds in excess of 80 miles an hour. There is some water seepage at the slit, but this can be eliminated. On one occasion I was able to observe Mars during a 50-mile-an-hour gale with the slit open only 3″.

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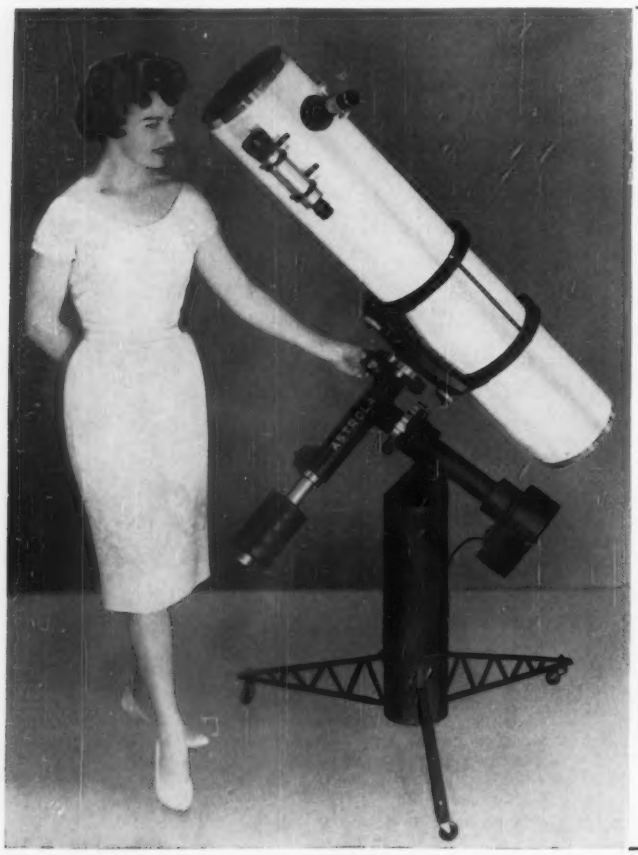

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Here we present our new 8″ f/6 De Luxe ASTROLA on a portable equatorial mounting with clock drive, setting circles, 8 x 52-mm. finder, and three of the finest orthoscopic oculars. This telescope can be completely disassembled in less than three minutes.

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Cat. No. $2300 ..... **$18.00**

Wide-Angle Erfle

Brand-new eyepiece with 68° field; coated. E.F.L. 1¼". Focusing mount, 3 perfect achromats, 1-13/16" aperture.

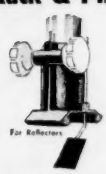
Cat. No. $1020 ..... **$13.50 ppd.**
Cat. No. $1593 1¼"-diam. ADAPTER for eyepiece above ..... **3.95 ppd.**

An Economical Eyepiece

This mounted eyepiece has two magnesium-fluoride-coated achromatic lenses 29 mm. in diameter. Excellent definition. E.F.L. 1¼". Cell fits 1¼" tubing.

Cat. No. $1911 Coated ..... **$5.90 ppd.**
Cat. No. $1991 Not Coated ..... **5.25 ppd.**

Rack-&-Pinion Eyepiece Mounts



Here is a wonderful opportunity for you to own a most mechanically perfect Rack-&-Pinion Focusing Eyepiece Mount with variable tension and adjustment. Will accommodate a standard 1¼" eyepiece, positive or negative. The body casting is made of lightweight aluminum with black-crackle paint finish, focusing tube of chrome-plated brass. Focusing tube for refractors has a travel of 4", for reflectors 2". Mount will fit all size tubing.

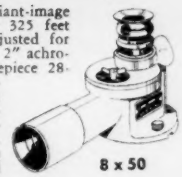
REFRACTOR TYPE

Cat. No. $1494 for 2⅛" I.D. Tubing ..... **$12.95 ppd.**
Cat. No. $1495 for 3¼" I.D. Tubing ..... **12.95 ppd.**
Cat. No. $1496 for 4⅜" I.D. Tubing ..... **12.95 ppd.**

REFLECTOR TYPE

Cat. No. $1976 (less diagonal holder) ..... **$8.50 ppd.**
Cat. No. $1982 DIAGONAL HOLDER ..... **1.00 ppd.**

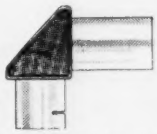
8-Power Elbow Telescope



This telescope has a brilliant-image 48° apparent field; actually 325 feet at 1,000 yards. Can be adjusted for focusing 15 feet to infinity. 2" achromatic objective, focusing eyepiece 28-mm. f.l., Amici erecting system. Turret-mounted filters: clear, red, amber, and neutral. Lamp housing to illuminate reticle for night use. Truly the biggest bargain you were ever offered. Original Gov't. cost $200.

Cat. No. $1686 Not Coated ..... **$13.50 ppd.**
Cat. No. $1975 Coated ..... **17.50 ppd.**

Star Diagonals



Guaranteed to make viewing the heavens with a refractor telescope 100% easier for the observer. Stop needless crouching forever. Choose the STAR DIAGONAL that best suits your requirements. Slides into standard 1¼" eyepiece mounts. Chromium tubes and aluminum housing, attractive black-crackle finish.

AMICI STAR DIAGONAL WITH ERECT IMAGE

For comfortable viewing of terrestrial or astronomical objects. The Amici prism gives an erect image.

Cat. No. $2095 ..... **$12.00 ppd.**

RIGHT-ANGLE PRISM STAR DIAGONAL

Contains a high-quality aluminized right-angle prism. wide field. Practical for astronomical use.

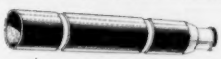
Cat. No. $2096 ..... **$12.00 ppd.**

MIRROR STAR DIAGONAL

Diagonal houses an excellent first-surface mirror, flat to within ¼ wave. Important accessory for refractor telescopes.

Cat. No. $2097 ..... **$12.00 ppd.**

7 x 30 Wide-Field Finderscope



Newly designed wide-field finderscope for reflector or refractor. Featured in this handsomely conceived black anodized aluminum tube are a 30-mm. coated achromatic objective, a wide-field Kellner eyepiece, and the all-important true crossline reticle for fast, exact locating. Compact and lightweight, 9" long, 1⅛" diam., 9 oz. May also be used as a hand-held telescope, offering excellent extra-wide-field views of the sky.

Cat. No. $2193 ..... **$9.75 ppd.**

Finder Ring Mounts

Made of cast aluminum with black crackle finish. Each ring has three locking wing screws for adjusting. Base has two holes for mounting screws, and fits any diameter tubing. Easy to attach. Ring mount No. S1963 will accommodate finder above.

Cat. No. $1963 .. 1-15/16" I.D. .. **Per Pair, $3.95 ppd.**
Cat. No. $1964 .. 2-11/16" I.D. .. **Per Pair, 3.95 ppd.**

New Prismatic Telescope

Coated **80-mm. Objective**

Big 80-mm.-diam. (3⅛") objective, for spotting or astronomical use. Will show stars of the 11th magnitude — 100 times fainter than the faintest visible to the naked eye. Table-top tripod included, extended 18", closed 13¼". Length of scope 16¼". Combined weight of scope and tripod is 5¼ lbs. All coated optics.

FIVE EYEPIECES

Power	Field at 1,000 yards	Exit pupil diam.	Relative brightness
15x	122 ft.	5.4 mm.	29
20	81	4.0	16
30	61	2.7	7
40	49	2.0	4
60	32	1.3	1

Cat. No. $2052 ..... **$59.50 ppd.**

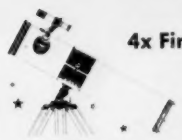
60-mm.-diam. Scope. Same as above but with smaller objective. Equipped with same five eyepieces — 15x, 20x, 30x, 40x, 60x. Coated. With tripod.

Cat. No. $1721 ..... **$42.95 ppd.**

4" Reflector Telescope

45x-225x

4x Finder — Wood Tripod



Study the sun and its spots. Observe galaxies, clusters, nebulae, and the Milky Way. Enjoy the thrill of being able to pick out small craters on the moon and see detail in the larger craters. A beautiful lunar landscape is brought to your doorstep. Bring distant events close to you; witness nature in action — eclipses, heavenly objects, and orbiting satellites. A high-quality telescope with an f/9 mirror. It has three eyepieces, 4-mm. (225x), 6-mm. (150x), 20-mm. (45x), and a free Barlow lens which will double the power. This will give 90x with the 20-mm. eyepiece, and 300x with the 6-mm. if observing conditions permit. Equipment tray keeps eyepieces clean and at hand. Sun and moon filters are included. Collapsible wood tripod makes scope portable, gives it stability and compactness. Finished in gray enamel with black trim. Imported. Shipping weight about 20 lbs.

FREE BARLOW LENS PLUS FREE BOOK "DISCOVER THE STARS" will come with scope.

Cat. No. $2273 ..... **f.o.b. Lynbrook, N. Y., $59.50**

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Beautifully styled imported binoculars. Precision made.

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"Zeiss" Type

Complete with carrying case and straps. American type offers a superior one-piece frame and clean design. Individual Focus (IF) or Center Focus (CF).

Cat. No.	Size	Field at 1,000 yards	Type	Price, ppd.
$1149	6 x 15 IF	360 ft.	Opera	$12.75
$1436	6 x 30 CF	395	"Zeiss"	18.75
$1435	6 x 30 CF	395	"Zeiss"	16.75
$1438	7 x 35 CF	341	"Zeiss"	20.75
$1437	7 x 35 IF	341	"Zeiss"	17.95
$1771	7 x 35 CF	341	American	23.50
$1439	7 x 35 CF	578	American*	35.00
$2191	7 x 50 CF	530	American**	42.50
$1106	7 x 50 CF	372	"Zeiss"	24.95
$-961	7 x 50 IF	372	"Zeiss"	22.50
$1503	7 x 50 CF	372	American	32.50
$1443	8 x 30 CF	393	"Zeiss"	21.00
$1229	8 x 30 IF	393	"Zeiss"	18.25
$1108	10 x 50 IF	275	"Zeiss"	26.75
$1442	20 x 50 CF	183	"Zeiss"	33.75

*Wide-angle 11° **Wide-angle

Add 10% Federal tax to all prices above.

Monoculars

Brand new, coated optics, complete with pigskin case and neck straps.

Cat. No. $1576 ..... **6 x 30** ..... **$10.00 ppd.**
Cat. No. $1577 ..... **8 x 30** ..... **11.25 ppd.**
Cat. No. $1578 ..... **7 x 35** ..... **12.50 ppd.**
Cat. No. $1303 ..... **7 x 50** ..... **14.75 ppd.**
Cat. No. $1579 ..... **16 x 50** ..... **17.50 ppd.**
Cat. No. $1580 ..... **20 x 50** ..... **20.00 ppd.**

New! Zoom Binoculars

Six different powers at your fingertips in the same binocular: 7x, 8x, 9x, 10x, 11x, and 12x. Positive fingertip control accomplished by rotation of eyecups. Popular Center Focus, American type, 40-mm. objectives, all coated optics. Complete with carrying case and straps. **Add 10% Federal tax.**

Cat. No. $2303 ..... **$39.75 ppd.**

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NOW for a mere $55 down— YOU can own this UNITRON

Here is one of the most popular refracting telescopes for the amateur astronomer who wishes to combine both visual observation and astrophotography. Optically excellent, this instrument also has the very precise mechanical adjustments so essential for serious work. And the low 10% down payment is well within the average budget.

Model 145 is supplied complete with equatorial mounting and slow-motion controls, tripod, 2.4" photographic guide telescope with star diagonal and crosshair eyepiece, 10x 42-mm. view finder, 6 eyepieces, choice of UNIHEX Rotary Eyepiece Selector or Star Diagonal and Erecting Prism System, achromatic amplifier, sun projection screen, sunglass, UNIBALANCE tube assembly, cabinets, and so forth, all for only $550. Extra eyepieces are available to permit a total of nine magnifications ranging from 30x to 300x.

If your interest lies only in visual observation, then we suggest UNITRON Model 142, the regular 3" Equatorial, priced at only $435 complete (down payment $43.50).

There is a UNITRON 3" Altazimuth model for as little as $265, complete, and other UNITRON Refractors are priced as low as $75. All may be purchased for only 10% down using our Easy Payment Plan. Whichever model you choose, you are assured of obtaining the finest instrument in its class.

After all, like thousands of others, you can place your confidence in UNITRON.

3-inch PHOTO-EQUATORIAL

ACCESSORIES to Modernize Your Telescope

Many of the accessories and components pictured on Model 145 are available separately, to fit telescopes of various sizes.

ASTRO-CAMERA 220: complete with accessories	$ 69.50
PHOTOGRAPHIC GUIDE TELESCOPE: with brackets and accessories	75.00
VIEW FINDER: 10x, 42-mm. with mounting brackets	18.00
EQUATORIAL MOUNTING and TRIPOD: with cabinet	198.00
UNIHEX ROTARY EYEPIECE SELECTOR: for rapid change of eyepieces	24.75
UNICLAMP CAMERA BRACKET: for 3" refractor	3.75
OBJECTIVE LENS: 3", coated, air-spaced, in cell	69.00
RACK-AND-PINION MECHANISM: with drawtube	Prices from $12.50

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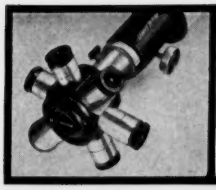


UNITRON
MONTHLY REPORT TO OBSERVERS

SEE THE BACK COVER FOR MORE NEWS ABOUT *UNITRON*

constellation of the month

URSA MAJOR

As twilight fades into darkness on a fine August evening, the Big Dipper can be seen hanging from its handle, halfway up the northwestern sky. Its outline is marked by seven bright stars glittering in the deep blue. For many people around the world who enjoy naked-eye viewing of the constellations, this famous star pattern is the first one learned.

For most new UNITRON owners, one of the first telescopic observations is Mizar, the next-to-last star in the Dipper's handle. Even with the unaided eye, you will see that 2nd-magnitude Mizar has a close neighbor, 5th-magnitude Alcor. In a 1.6-inch UNITRON with moderately high power, Mizar and Alcor are widely separated, while Mizar itself is resolved into a beautiful double star. Its members are magnitudes 2 and 4, with a separation of 14 seconds of arc.

Anyone fortunate enough to have just acquired a UNITRON should try the following simple experiment. Attach the UNIHEX Rotary Eyepiece Selector, then look at the Mizar field through each of your eyepieces in quick succession, from lowest power to highest, in order. This is an excellent way to learn how size and scale of the view field change with increasing magnification.

The constellation boundaries of Ursa Major extend far outside the Dipper itself, which forms only the body and tail of the Great Bear. Many interesting double stars in this large constellation await observers armed with UNITRONS. For example, Xi Ursae Majoris is a famous binary, whose 5th-magnitude companion takes 60 years to complete one trip around its 4½-magnitude primary. This summer, the two stars are separated by 2.3 seconds of arc. A UNITRON 3-inch with a high-power ocular should split this pair on a good night.

The many galaxies of Ursa Major form a special attraction for observers with larger UNITRONS. M81 and M82 are two remote spirals, less than a degree apart on the sky, and M101 is near the end of the Dipper handle. A large, dim planetary nebula, M97, is located about a third of the way from Beta Ursae Majoris to Gamma. A very clear, dark night is best for observing it.

MANY Models To Choose From!

2" SATELLITE ($7.50 Down) 6x, diagonal eyepiece, altazimuth mount with circles, stand — **$75**

1.6" ALTAZIMUTH ($7.50 Down) with eyepieces for 78x, 56x, 39x — **$75**

2.4" ALTAZIMUTH ($12.50 Down) with eyepieces for 100x, 72x, 50x, 35x — **$125**

2.4" EQUATORIAL ($22.50 Down) with eyepieces for 129x, 100x, 72x, 50x, 35x — **$225**

3" ALTAZIMUTH ($26.50 Down) with eyepieces for 171x, 131x, 96x, 67x, 48x — **$265**

3" EQUATORIAL ($43.50 Down) with eyepieces for 200x, 131x, 96x, 67x, 48x — **$435**

4" ALTAZIMUTH ($46.50 Down) with eyepieces for 250x, 214x, 167x, 120x, 83x, 60x — **$465**

4" EQUATORIAL ($78.50 Down) with eyepieces for 250x, 214x, 167x, 120x, 83x, 60x, 38x — **$785**

4" EQUATORIAL with clock drive **($98.50 Down)**, Model 160V, eyepieces as above — **$985**

4" EQUATORIAL with clock drive and metal pier **($107.50 Down)**, Model 166V, eyepieces as above — **$1075**

4" PHOTO-EQUATORIAL with clock drive and Astro-camera **($117.50 Down)**, eyepieces for 250x, 214x, 167x, 120x, 83x, 60x, 38x, 25x — **$1175**

4" PHOTO-EQUATORIAL with clock drive, pier, Astro-camera **($128.00 Down)**, eyepieces for 375x, 300x, 250x, 214x, 167x, 120x, 83x, 60x, 38x, 25x — **$1280**

6" EQUATORIAL with clock drive, pier, 2.4" view finder, eyepieces for 625x, 500x, 416x, 357x, 277x, 200x, 138x, 100x, 62x, 42x — **$5125**

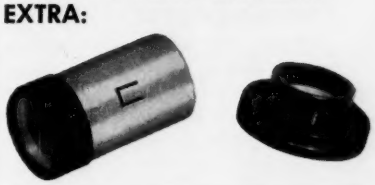
UNITRON accessory of the month

VIEW FINDERS

Adding one of UNITRON's popular view finders is an inexpensive way to modernize and increase the efficiency of your present telescope. All models are supplied complete with brackets and collimating screws as well as the screws needed to attach the finder to your tube. View finders and guide telescopes of 62-mm. and 100-mm. are also available for telescopes of large aperture.

1. **VIEW FINDER,** 23.5-mm. (.93"), 6x eyepiece. **Postpaid, only $8.50**
2. **VIEW FINDER,** 30-mm. (1.2"), 8x eyepiece. **Postpaid, only $10.75**
3. **VIEW FINDER,** 42-mm. (1.6") air-spaced objective, 10x eyepiece. This finder measures approximately 16" over-all. It is light in weight, compact, and small enough to use as a hand telescope furnishing spectacular wide-field views of the sky. **Postpaid, only $18.00**

ANOTHER NEW UNITRON EXTRA:



In this case, UNITRON's brand new Achromatic Amplifier — a two-element, color-corrected Barlow-type negative amplifying lens designed especially for UNITRON Refractors.

What's good about it is this: When used with a UNITRON eyepiece, it doubles normal magnification to increase the usefulness of each eyepiece. Two types of mounting cells are available, one to fit the UNIHEX Rotary Eyepiece Selector, and one for the UNITRON Star Diagonal. It's easy to use, and there's never any adjustment of eyepiece (or star diagonal) necessary. What's best about the new Achromatic Amplifier is that it is now included with every UNITRON at no additional cost.

HOW TO ORDER A UNITRON

Send check or money order in full or use our Easy Payment Plan. Shipments made express collect. Send 20% deposit for C.O.D. shipment. UNITRON instruments are fully guaranteed for quality, workmanship, and performance, and must meet with your approval or your money back. Prices of UNITRON refractors include basic accessories, eyepieces, tripod and mounting, fitted cabinets, and instructions.

USE OUR EASY PAYMENT PLAN

UNITRON's popular Easy Payment Plan is a convenient and economical way to buy your UNITRON Refractor. The down payment required is 10%. The balance due is payable over a 12-month period, and there is a 6% carrying charge on the unpaid balance. Your first payment is not due until 30 days after you receive the instrument, and if you should want to pay the entire balance due at that time, the carrying charge is cancelled.

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- Hints for observers
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CELESTIAL CALENDAR

Universal time (UT) is used unless otherwise noted.

The Eclipsing Variable OO Aquilae

In the same finder field with brilliant Altair lies the eclipsing variable star OO Aquilae, near the point of a prominent fishhook of 9th- and 10th-magnitude stars. OO Aquilae is a fine example of the W Ursae Majoris type of binary, with a period of 0.5068 day (12.16 hours).

At maximum light the variable is of magnitude 9.9. During each half-day cycle it has two maxima and two slightly unequal minima, magnitudes 10.09 and 10.05. As the light curve shows, the brightness is continuously changing, unlike the more familiar eclipsing binaries of the Algol variety, which have practically constant light over most of the period.

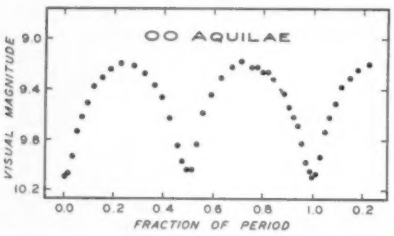
The variability of OO Aquilae was discovered by Dorrit Hoffleit in 1932 on Harvard Observatory photographs. It is perhaps the best suited of all the W Ursae Majoris stars for amateur observation because it is easy to find, there is a convenient field of comparison stars, and it has a relatively large brightness range. Although a 3-inch telescope will show OO, a greater aperture is recommended for systematic estimates of its magnitude, say, a 6-inch. A worth-while experiment is to observe OO Aquilae at 15-minute intervals during a long night's work, when a minimum is scheduled. The 1950 co-ordinates of this star are $19^h\ 45^m.8$, $+9°\ 11'$.

During August, primary minima of OO Aquilae will occur at the following Universal times, expressed in hours and tenths. Adding or subtracting 6.1 hours from any of the listed times furnishes predictions of the secondary minima.

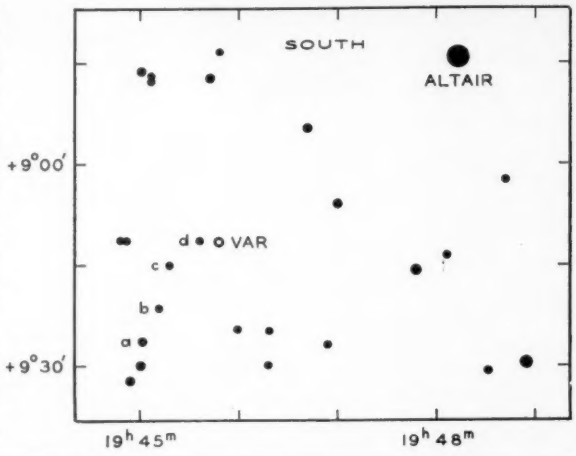
August 1, $11^h.6$, $23^h.8$; 2, $11^h.9$; 3, $0^h.1$, $12^h.2$; 4, $0^h.4$, $12^h.6$; 5, $0^h.7$, $12^h.9$; 6, $1^h.1$, $13^h.2$; 7, $1^h.4$, $13^h.6$; 8, $1^h.7$, $13^h.9$; 9, $2^h.0$, $14^h.2$; 10, $2^h.4$, $14^h.5$; 11, $2^h.7$, $14^h.9$; 12, $3^h.0$, $15^h.2$; 13, $3^h.3$, $15^h.5$; 14, $3^h.7$, $15^h.8$; 15, $4^h.0$, $16^h.2$; 16, $4^h.3$, $16^h.5$; 17, $4^h.7$, $16^h.8$; 18, $5^h.0$, $17^h.1$; 19, $5^h.3$, $17^h.5$; 20, $5^h.6$, $17^h.8$; 21, $6^h.0$, $18^h.1$; 22, $6^h.3$, $18^h.5$; 23, $6^h.6$, $18^h.8$; 24, $6^h.9$, $19^h.1$; 25, $7^h.3$, $19^h.4$; 26, $7^h.6$, $19^h.8$; 27, $7^h.9$, $20^h.0$; 28, $8^h.2$, $20^h.4$; 29, $8^h.6$, $20^h.7$; 30, $8^h.9$, $21^h.0$; 31, $9^h.2$, $21^h.4$.

September 1, $9^h.6$, $21^h.7$; 2, $9^h.9$, $22^h.0$; 3, $10^h.2$, $22^h.4$.

The periods of many W Ursae Majoris stars lengthen or shorten slightly from year to year. So far, OO has shown little evidence of this, but instability could set in unexpectedly. More timings of its minima are needed.



Left: D. Martinov's light curve of OO Aquilae, from 952 visual observations. The 12-hour period is counted from one primary minimum to the next; midway between them occurs a secondary minimum of almost equal depth. From "Publications" of Engelhardt Observatory.



Right: Stars to magnitude 10 are plotted in a finder chart for OO Aquilae. Dr. Martinov gave visual magnitudes for comparison stars: a, 8.84; b, 9.09; c, 9.81; d, 10.26.

August Meteors

The rich Perseid meteor shower can be readily observed this year, for at predicted maximum on August 11-12 the moon will be only one day old. On that night, up to 50 meteors per hour should be visible. Few will appear before midnight, the number increasing sharply toward dawn. Although occurring in all parts of the sky, Perseids will seem to radiate from right ascension $3^h\ 04^m$, declination $+58°$, near the Cassiopeia-Perseus border. Lesser numbers of Perseid meteors should be visible for a week before and a week after the 12th. The radiant moves eastward among the stars about 1⅓ degrees per day.

WILLIAM H. GLENN

Moon Phases and Distances

Last quarter	August	3, 11:48
New moon	August	11, 10:36
First quarter	August	19, 10:52
Full moon	August	26, 3:14
Last quarter	September	1, 23:06

August	Distance	Diameter
Apogee 11, 17^h	252,600 mi.	29′ 24″
Perigee 25, 19^h	222,000 mi.	33′ 26″
September		
Apogee 7, 20^h	252,400 mi.	29′ 25″

Aldebaran Occultation

On August 5th a daylight occultation of Alpha Tauri by the moon will be visible across the United States. The star will disappear near midday at the bright edge of the 23.9-day moon and reappear at the dark edge. Unless the sky is perfectly clear, the event will be extremely difficult to observe, and care should be taken to keep any direct sunlight from entering the telescope tube. Predicted times for all stations can be obtained from the Occultation Supplement in the December, 1960, issue of Sky and Telescope.

Minima of Algol

August 1, 4:02; 4, 0:51; 6, 21:40; 9, 18:28; 12, 15:17; 15, 12:06; 18, 8:54; 21, 5:43; 24, 2:32; 26, 23:20; 29, 20:09.

September 1, 16:58; 4, 13:47; 7, 10:35.

These minima predictions for Algol are based on a recent timing by D. Engelkemeir, and an assumed period of 2.8674 days. The times given are geocentric; they can be compared directly with observed times of least brightness.

Minor Planet Predictions

Pallas, 2, 8.8. August 9, 23:21.4 +6-24; 19, 23:16.2 +4-53; 29, 23:09.6 +3-01. September 8, 23:02.2 +0-55; 18, 22:54.7 −1-19; 28, 22:47.8 −3-33. Opposition on September 7th.

Flora, 8, 8.3. August 19, 23:42.9 −11-09; 29, 23:37.4 −12-40. September 8, 23:29.6 −14-13; 18, 23:20.8 −15-35; 28, 23:12.6 −16-34. October 8, 23:06.4 −17-02. Opposition on September 13th.

Juno, 3, 8.0. August 29, 23:53.5 +0-01. September 8, 23:48.2 −1-52; 18, 23:41.6 −3-58; 28, 23:34.7 −6-06. October 8, 23:28.6 −8-02; 18, 23:24.5 −9-37. Opposition on September 18th.

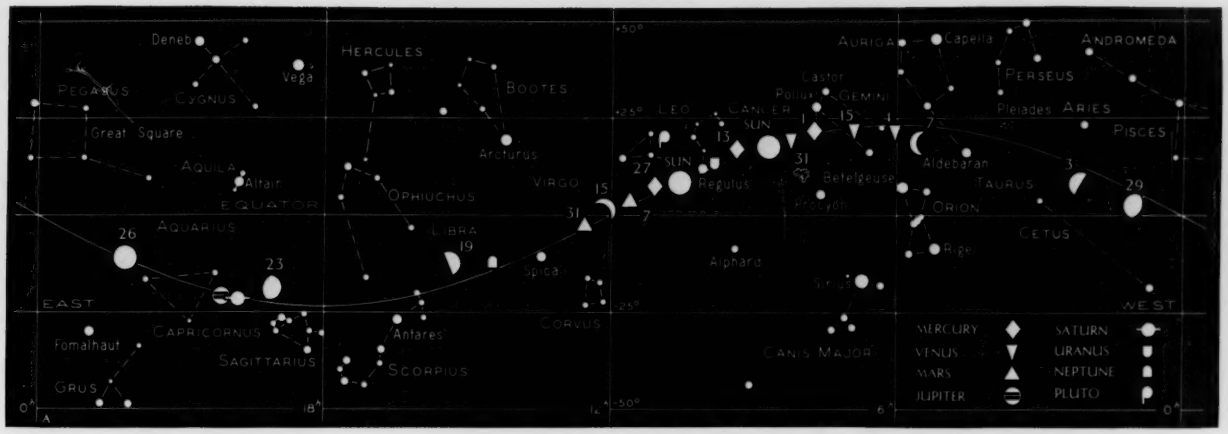
After the asteroid's name are its number and the approximate visual magnitude expected at opposition. At 10-day intervals are given its right ascension and declination (1950.0) for 0^h Universal time. In each case the motion of the asteroid is retrograde. Data are supplied by the IAU Minor Planet Center at the University of Cincinnati Observatory.

Variable Star Maxima

August 6, T Eridani, 035**124,** 8.0; 9, W Ceti, 235**715,** 7.6; 13, R Reticuli, 043**263,** 7.6; 13, S Canis Minoris, 072708, 7.5; 16, R Caeli, 043**738,** 7.9; 18, R Virginis, 123307, 6.9; 25, RS Librae, 151**822,** 7.5; 30, S Virginis, 132**706,** 7.0.

September 6, RT Cygni, 194048, 7.3; 7, T Centauri, 133**633,** 5.5.

These predictions of variable star maxima are by the AAVSO. Stars are listed only if brighter than magnitude 8.0 at an average maximum. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for their maxima. The data given include, in order, the day of the month near which the maximum should occur, the star name, the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern), and the predicted visual magnitude.



THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month or for other dates shown. All positions are for 0^h Universal time on the respective dates.

The sun will be annularly eclipsed on August 11th along a path extending across the South Atlantic Ocean and terminating in Antarctica (see pages 30-31 last month). The maximum duration of the annular phase will be 6.6 minutes. Partial eclipse will be visible in eastern South America and southern Africa.

Mercury will be too close to the sun all month for observations to be feasible. It reaches superior conjunction on the 14th, and thereafter will be an evening object.

Venus, rising about three hours before the sun, is a brilliant object of magnitude −3.5, greatly outshining Pollux, which will be 7½° north of the planet on August 24th. On that date, Venus' gibbous disk will be three-fourths illuminated and 14″ in diameter. Watch for the planet and the waning crescent moon on the morning of the 7th, as they will be in conjunction at 18^h Universal time that day.

The moon will be partially eclipsed on August 26th at 3^h UT for observers in western Asia, Africa, Europe, and the Americas. At maximum eclipse less than one per cent of the moon's diameter will be outside the earth's shadow. Full details are given on page 92.

Mars is in Virgo, setting about 1½ hours after the sun, but it will not be easily seen as it has faded to magnitude +1.9.

Jupiter, in Capricornus, crosses the meridian 3½ hours after sunset in mid-month. It is very brilliant, of magnitude −2.3. Telescopically, the planet shows a slightly flattened disk 44″.3 in polar diameter and 47″.4 in equatorial. The moon will pass 3° north of Jupiter at 23^h UT August 23rd.

Saturn is in Sagittarius some 5° west of Jupiter, rising about 1½ hours before sunset and being visible in the southern sky until just before dawn. Although Jupiter outshines it, the ringed planet is brighter than Antares to the southwest. In the middle of the month its strongly flattened telescopic disk will have an equatorial diameter of 18″.3. The ring system will be 41″.3 across, the northern face being visible.

Uranus is in conjunction with the sun on August 19th, and too close to it to be seen this month.

Neptune is in Libra, at right ascension 14^h 27^m.1, declination −12° 42′ (1950 co-ordinates) on the 15th. In small telescopes, Neptune is indistinguishable in appearance from an 8th-magnitude star, but large instruments will show its tiny disk, 2″.4 in diameter.

WILLIAM H. GLENN

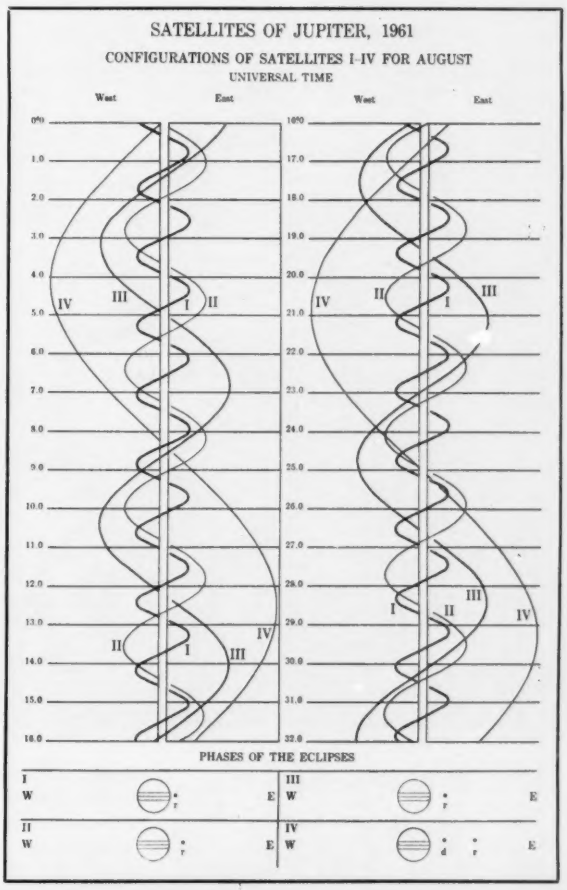
UNIVERSAL TIME (UT)

TIMES given in Celestial Calendar are Universal time (Greenwich civil time) unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. To obtain daylight saving time subtract 4, 5, 6, or 7 hours respectively. If necessary, add 24 hours to the UT before subtracting, in which case the result is your standard time on the day preceding the Greenwich date shown. For example, 6:15 UT on the 15th of the month corresponds to 1:15 a.m. EST on the 15th and to 10:15 p.m. PST on the 14th.

JUPITER'S SATELLITES

The four curving lines represent Jupiter's four bright (Galilean) satellites: I, Io; II, Europa; III, Ganymede; IV, Callisto. The location of the planet's disk is indicated by the pairs of vertical lines. When a satellite passes in front of Jupiter, its curve crosses the lines. If a moon is invisible because it is occulted by Jupiter or is in its shadow, the curve is broken.

For successive dates, the horizontal lines mark 0^h Universal time, or 7 p.m. Eastern standard time (4 p.m. Pacific standard time) on the preceding day. Along the vertical scale, 1/16 inch is about seven hours. In this chart, west is to the left, as in an inverting telescope for a Northern Hemisphere observer. At the bottom, "d" is the point of disappearance of a satellite in Jupiter's shadow; "r" is the point of reappearance. From the "American Ephemeris and Nautical Almanac."



SOUTHERN STARS

The sky as seen from latitudes 20° to 40° south, at 11 p.m. and 10 p.m., local time, on the 6th and 21st of September, respectively; also, at 9 p.m. and 8 p.m. on October 7th and 22nd. For other dates, add or subtract ½ hour per week.

Challenging to the naked eye are the second and third smallest constellations on the celestial sphere, Equuleus the Colt and Sagitta the Arrow. Look for them in the northwestern sky at chart time; they are separated only by little Delphinus, the Dolphin.

STARS FOR AUGUST

The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 7th and 22nd of August, respectively; also, at 7 p.m. on September 6th. For other dates, add or subtract ½ hour per week.

Hold the chart overhead, with "North" facing north. The equator, ecliptic, galactic equator, and meridian are indicated by dashed curves, as are the hour circles at three-hour intervals east and west of the meridian. The position of the north galactic pole is marked "X."

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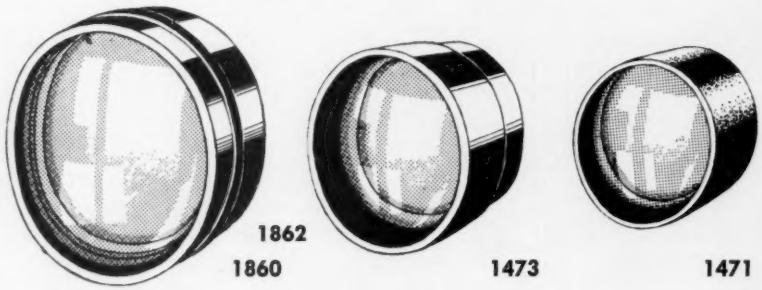

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$–952	2⅛"	23½"	12.50
$1431	2⅛"	30"	12.50
$1432	2⅛"	40"	12.50
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$1158	3⅛"	19½"	28.00
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$1507	6"	60"	25.00
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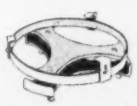

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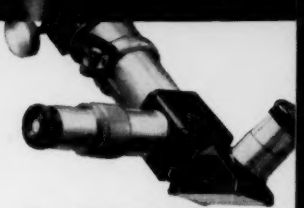

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